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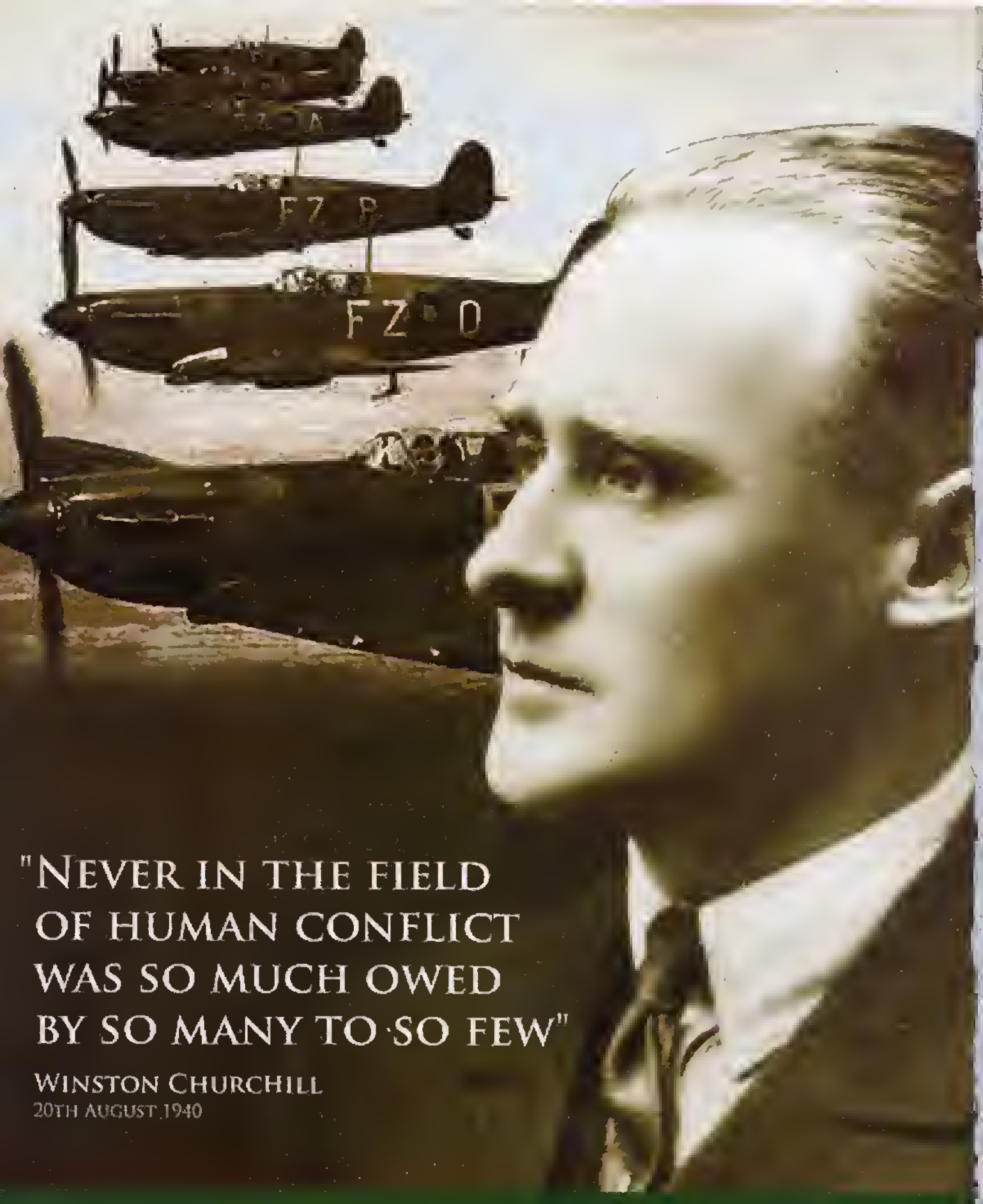

"NEVER IN THE FIELD OF HUMAN CONFLICT WAS SO MUCH OWED BY SO MANY TO SO FEW"

WINSTON CHURCHILL
20TH AUGUST 1940

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In a year in which the 60th anniversary of the end of World War Two will be commemorated (and in particular the notable events of VE and VJ Day), this magazine looks at the one piece of technology that played probably the greatest role in the conflict - the aeroplane.

Although the first aerial battles took place in the skies over northern Europe during World War One, it was not until the later conflict that this form of technology became a major weapon of war. As well as the roles pioneered by the aeroplane in 1914-18 - such as fighter, bomber and reconnaissance - during World War Two it carried out many new ones, noticeably those of fighter-bomber, night-fighter, airborne assault and transport.

Colossal numbers of aircraft were built during the six years from 1939 to 1945, leading to the development of new manufacturing techniques which revolutionised both commercial and military aircraft production in the post-war years. Technical development is one of the biggest legacies handed on to subsequent generations by the aircraft of that era. But the victory of freedom over evil and oppression is the greatest legacy of all - and much of this is owed not only to those who flew and fought then, but also to the thousands of designers, engineers and production line workers who created the many aircraft of World War Two.

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(Douglas Fisher Archive)

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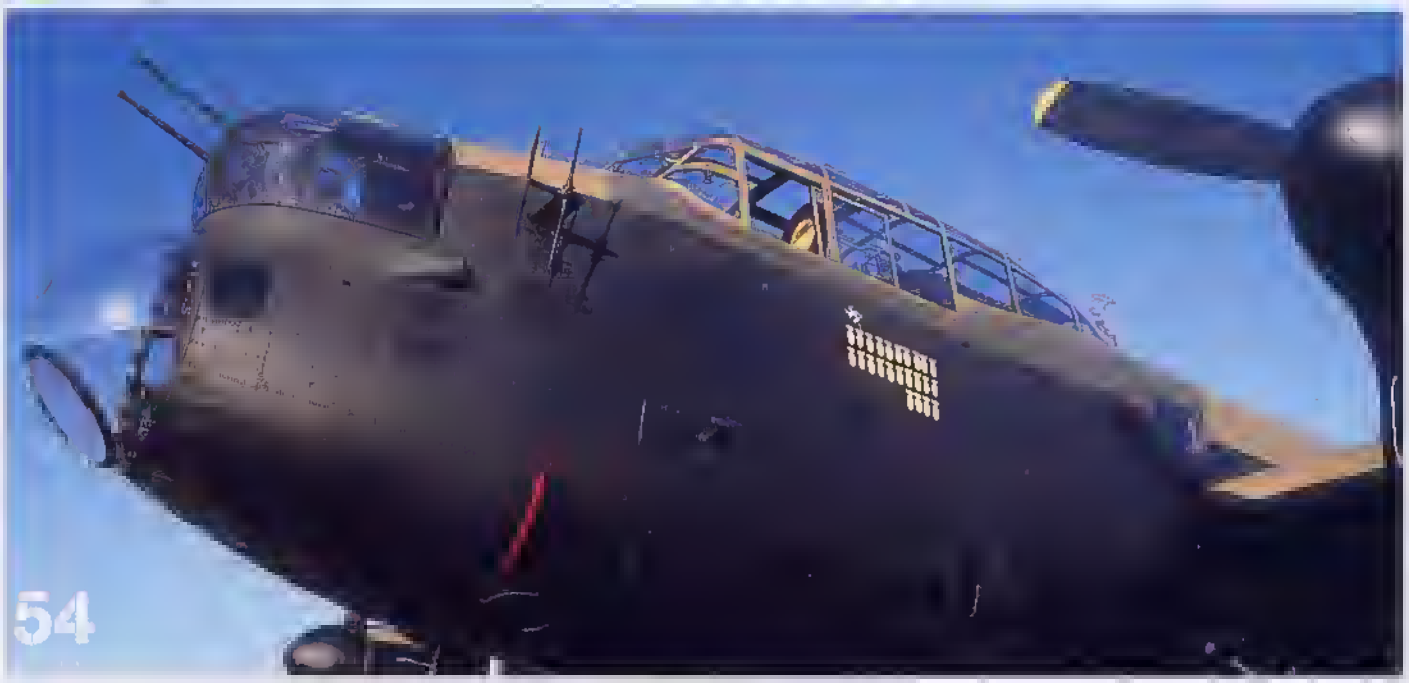
(Bundesarchiv BA 1011-471-1704-23A)



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(Warren Thompson)

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A NEW KIND OF WAR

THE WIDESPREAD USE OF AIRPOWER DURING WORLD WAR TWO MARKED A TURNING POINT IN THE EVOLUTION OF WARFARE. IT CHANGED THE NATURE OF ARMED CONFLICT FOREVER

The British Avro Lancaster epitomises the role played by the bomber during World War Two. The bomber, especially when used in large numbers, could cause massive destruction, often indiscriminately, and severely damage an enemy's war industries. (Key – Duncan Cubitt)

A Luftwaffe Dornier Do 17 – one of the many advanced aircraft available to the Germans when they launched their Blitzkrieg offensives in Europe between 1939 and 1940. (KEY collection)

The aeroplane first appeared in a combat role during the World War One, initially in an artillery spotting or reconnaissance role but later as a bomber and fighter. Some armed forces were slow to appreciate what the aircraft could offer to the battlefield, but to many others it represented a revolution.

During the 1920s aviation development was relatively slow but gradually monoplane designs and the use of all-metal construction began to surface. In Germany Adolf Hitler led the Nazis to power in the 1930s and the country was soon secretly rearming – a key element in this process were some advanced monoplane combat aircraft. Realising what was going on almost too late, other European countries sought to bolster their armed forces. But once Germany invaded Poland in September 1939 the situation in Europe reached crisis point and within three days, Britain and France had declared war on Germany. Their air forces were woefully ill-equipped to face the modern types being used by the Luftwaffe, and a frantic effort was made to increase aircraft performance and production rates.

Rapid development

Even before Winston Churchill became Prime Minister in May 1940 Britain's aircraft industry had begun to speed up the development of new aircraft to meet the growing German threat. Fortunately by this time Britain already had two superb new monoplane fighters – the Hawker Hurricane and the Supermarine Spitfire. But when the Battle of Britain started in July 1940 the RAF's fleet was still severely outnumbered.

At this juncture new technology, especially radar, played a vital part in Britain's war effort (see later) and in a way its introduction epitomises the rapid advances made by scientists and engineers throughout the war. Of course, such progress was also being matched by the opposition's experts. A good example of this was the RAF's use of Window (air-dropped aluminium strips) that could jam German ground-based radar, thus 'blinding' its night fighter controllers and preventing them from intercepting Bomber Command aircraft. Once the enemy realised what was going on it sought to use different radar wavelengths to get around the problem. The RAF countered again by dropping different lengths of Window to jam more frequencies. These examples are just a few of the many 'tit-for-tat' moves made by both sides throughout the conflict.

As will be detailed later in this magazine, the rate of aircraft development, establishment of mass production lines and advances in propulsion continued at an amazing rate, driven by the intensifying conflict. And for the battlefield commanders, aircraft were revolutionising the way they fought the war.

Diversity

When war broke out in 1939 the fighter and bomber remained the two primary combat types but the reconnaissance, transport and anti-shipping/submarine warfare roles were also being advanced. For the commander in the field this opened up a vast number of new opportunities and had a significant impact on the planning of various operations.

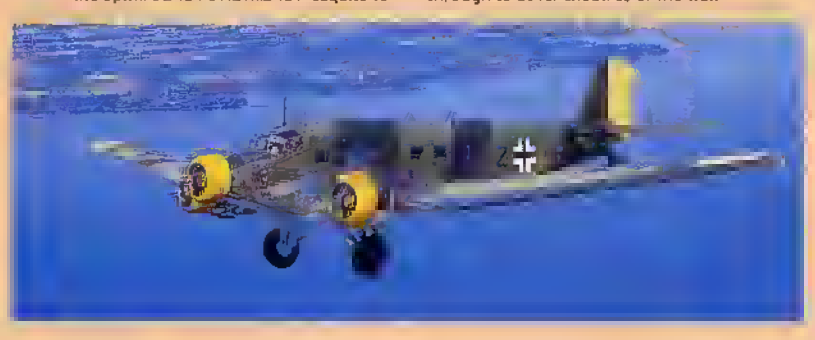
The Germans were quick to make full use of this new diversity, when carrying out the Blitzkrieg (lightning war) offensives (see pages 10-15) in Poland, the Low Countries and France in 1939 and 1940. The overwhelming number of Luftwaffe aircraft was one thing, but equally important was the way in which they were used. Aircraft such as the Junkers Ju 87 Stuka dive-bomber was employed in an early type of close air support role, working in liaison with the troops and armour on the ground to defeat an objective. Bombers were tasked to take out strategic objectives, such as bridges and transportation networks to hamper the movement of the enemy. Meanwhile fighters were not only used for air combat but also to attack and strafe airfields and key targets. This co-ordinated approach took the opposition forces by complete surprise and the term 'lightning war' proved very accurate as the Germans celebrated a quick succession of victories.

Just as they had in World War One, aircraft came into their own in the reconnaissance role, only now their use was more widespread. The RAF in particular made the most of high-flying assets, such as the Spitfire and de Havilland Mosquito to search out specific targets (such as the Battleship *Tirpitz*) or to perform pre- and post-strike missions over a target. Equally the Luftwaffe also employed specialised reconnaissance aircraft, such as the Junkers Ju 86, to photograph potential targets in Britain. Thanks to the technological advances made in photography, high-quality detailed images could be taken from the relative safety of high altitude to provide a wealth of information to commanders.

Before the war started a number of companies, most notably American ones, were making great strides in designing all-metal monoplane commercial airliners, such as the Douglas DC-3. Not surprisingly these were quickly adapted into military transports (in this case the C-47 Skytrain or Dakota), to move men, supplies and machinery to wherever they were required. However, it was the Luftwaffe that pioneered the use of airborne paratroops on the battlefield, with the Junkers Ju 52 making a particular name for itself in support of this role. The ability to use literally hundreds of aircraft at a time to fly in and drop thousands of paratroopers gave army commanders a great tactical advantage. Now you could advance on the ground, but also drop troops at strategic locations 'behind enemy lines' to launch two-pronged attacks.

Adolf Hitler and Hermann Göring (left) recognised the advantage that a strong air force would give them and they were proved correct in the early years of the war. However, Hitler's increasing interference in Luftwaffe tactics effectively thwarted the service's ability to fight effectively. (KEY collection)

This concept of airborne troops caught on and the Allies adopted it during the invasion of Sicily in 1943. But it was used on a grander scale on June 6, 1944, during the D-Day landings when British and American airborne troops were dropped in darkness to secure vital targets in advance of the naval landings on the five invasion beaches in Normandy. The ambitious but unsuccessful Operation Market Garden to secure bridges over the Rhine in Holland in late 1944 also relied heavily on paratroops and the tactic gradually filtered through to other theatres of the war.



The Junkers Ju 52 transport aircraft helped the Germans to pioneer the use of airborne paratroops. The rugged tri-motor design served the Luftwaffe on all fronts throughout the war. (KEY - Duncan Cubitt)

Carrier-borne air power was extensively exploited by the US Navy. The Douglas SBD Dauntless dive-bomber was one of its most effective wartime aircraft and almost single-handedly the type won the Battle of Midway in June 1942. (Planes of Fame Museum)

The US Army Air Corps (USAAC) had demonstrated the capabilities of aircraft against shipping not long after World War One but during World War Two the role would take on particular significance. While land-based aircraft were extensively used against shipping throughout the war, it was the aircraft carrier that most influenced naval tactics. The Royal Navy enjoyed some notable successes with its Fairey Swordfish biplanes against the battleship *Bismarck* and the Italian fleet in Taranto, but it was the US Navy that really maximised the potential of the carrier.

The carrier's most dramatic contribution during the war came during the Imperial Japanese Navy's surprise attack on Pearl Harbor on December 7, 1941, which brought America into the war. The Japanese used a combined force of carrier-based dive-bombers and torpedo planes to inflict serious damage on the American fleet, but the American aircraft carriers were not in port at the time. This was crucial and in June 1942 the Americans surprised the Japanese at the Battle of Midway, sinking four of their carriers and marking a major turning point in the Pacific war. This, coupled with the huge industrial capacity of the USA, meant that it was not long before dozens of US Navy carriers were on the offensive against Imperial forces in the western Pacific.

Aircraft carriers also provided a platform from which to launch close air support missions for the troops that had just landed on the beaches of Pacific islands. The US Marines made particular use of this technique, calling in aircraft to carry out precision strikes on enemy strong points and defensive positions. Such methods are now a vital part of modern day warfare.

To combat the U-boat menace in the North Atlantic, the British and later the Americans employed a variety of aircraft to try to spot and destroy enemy submarines while they were vulnerable on the surface. Using bombs and depth charges these aircraft eventually proved very effective, especially when fitted with airborne search radar (see pages 18-21). Again, this was a new type of warfare, but since World War Two it has become an integral part of modern combat, particularly for those nations with extensive coastal boundaries.

Rapid evolution

World War Two resulted in aircraft being applied to many different areas of combat and for providing commanders with a new weapon with which to execute their battle plans. The bomber was a vital tool in this process and its first major use was in the hands of the Luftwaffe against Britain in 1940/41. Once America entered the war and joined the British on bombing missions from the UK, the tide began to turn against the Nazis. Bomber Command flew area bombing missions at night, while the USAAF undertook more accurate daylight attacks against strategic targets and together they enabled commanders to hit the enemy's war industry, communications network and oil supplies almost around the clock. Without this capability, the war would have undoubtedly lasted much longer.

It was a similar story in the Pacific once the Americans had secured airfields within striking distance of the Japanese mainland. Large formations of B-29 Superfortresses caused havoc to Japanese armaments production and cities, and in the end it was two B-29s dropping two atomic bombs that brought the conflict to a close.

There can be no doubt that the aircraft was one of the most important weapons used in World War Two. But as well as giving commanders completely new tactics and capabilities, it also brought death and destruction on an almost unimaginable scale, with cities laid waste and millions killed or displaced.

Yet at the same time, aircraft development created brand new industries and a wealth of technological advances that laid the foundations for today's aviation industry and the establishment of mass production techniques. It's unlikely that modern airliners would be as sophisticated as they are now, had it not been for the work done accomplished by Boeing and Douglas during the war. Aerodynamics and aircraft propulsion made massive leaps during the six years of the conflict, resulting in the world's first jet-powered fighter aircraft and the application of the swept wing for high-speed flight. Combat was revolutionised by the use of aircraft during World War Two and since those dark days it has remained arguably the most potent weapon in a nation's arsenal. ■

Close air support was pioneered by the US Marine Corps, testimony to which are the bombing mission marks adorning this F4U Corsair on a Pacific island in 1944. (Ed Szrejter via Warren Thompson)

Mass production techniques developed quickly during the war but although the British and Germans managed to achieve some credible production figures, the Americans still led the way. Here brand new Lockheed P-38 Lightnings await delivery – daily production rates of some types approached 20 aircraft, even the Boeing B-17 Flying Fortress peaked at 16 aircraft a day in 1944. (KEY collection)

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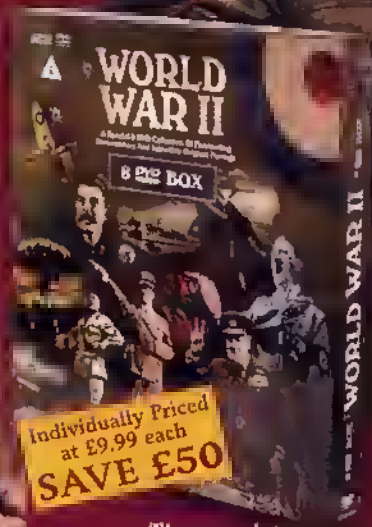

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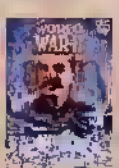

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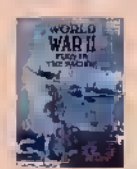

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BLITZKRIEG!

THE CONCEPT OF LIGHTING WAR USED BY GERMANY IS INVESTIGATED BY JOHN WEAL, IN PARTICULAR THE INVOLVEMENT OF THE LUFTWAFFE.

On the northern front, operations on the opening morning of the war were bedevilled by a heavy ground mist. Fully bombed-up Stukas of StG 2 'Immelmann' await the first mission of the day surrounded by bombs already placed in position for their return and re-arming for a second planned sortie.

Opposite page: **Armourers prepare to reload a Messerschmitt Bf 109 during the Blitzkrieg offensive against Poland in September 1939.** (Bundesarchiv BA Bild 146-1997-026)

The era of Blitzkrieg was born on 04.26hrs on the morning of September 1, 1939. It was at that precise moment that the first of three Ju 87 Stuka dive-bombers of StG 1, led by Oberleutnant Bruno Dilley, lifted off from their base in East Prussia. Their objective was the steel latticework railway bridge spanning the River Vistula at Dirschau. Their mission: not to destroy the bridge, but to sever the cable connected to the demolition charges placed under it by the Polish Army in readiness to blow it up should Germany invade.

TARGET POLAND

The Poles had every reason to be concerned. Towards the end of that long hot summer of 1939 the tension in Europe was almost at breaking point. Over the past three years Hitler, using a mix of guile and sabre-rattling, had added huge swathes of territory to his Greater German Reich. Now his eyes were firmly fixed on Poland. It was clear that this time he was not just willing, but actually seeking, to go to war to get what he wanted. And the type of war he was preparing to unleash on his eastern neighbour was of an entirely new kind – Blitzkrieg, or 'lightning war'.

At that time most European nations still thought in World War One terms of trench warfare, static artillery duels and massed, measured advances over a broad front. Germany, with her inter-war army restricted to just 100,000 men by the terms of the Versailles Treaty, had to devise something more in keeping with her needs and capabilities. Learning from the mistakes of the earlier conflict (something the British and French significantly failed to do), Germany's generals developed the lumbering battlefield tanks of World War One into the equivalent of fast armoured cavalry. To this they added a tactical, close-support air-arm to produce a combined striking force strong enough to smash through any local enemy opposition, and mobile enough to exploit the breach thus opened up by advancing rapidly into the enemy's heartland. Such, in very simple terms, was the concept of Blitzkrieg.

One of the reasons for Hitler's going to war was to eradicate the 'iniquity' of the Polish Corridor. This was a strip of land some 60 miles wide, which was ceded to Poland after World War One to allow her access to the Baltic Sea. At the same time it physically separated Germany's easternmost province of East Prussia from the rest of the Reich. A single major railway line was the only permitted direct land link between isolated East Prussia and Berlin. And it was the Dirschau bridge, carrying this line across the Vistula, that Dilley and his two wingmen had been ordered to save from destruction.

Despite the widespread fog and ground-mist over much of the northern coastal plains, the Stukas found and destroyed the blockhouses that protected the demolition ignition points, severing the finger-thick cables running out to the bridge. But this first successful pinpoint dive-bomber attack of World War Two was ultimately abortive. The German armoured train sent to secure the bridge was delayed and the Poles managed to blow up its central spans before other German troops could reach the area.

The foggy conditions in the north, which severely disrupted Luftflotte (Air Fleet) 1's planned operations during the opening hours of the campaign, did not extend inland. To the south, Luftflotte 4 faced no such problems. And it was one of this Air Fleet's subordinate commands, Fliegerführer zbV (lit: Air Leader Special Purposes), that formed the aerial component at the core of the Blitzkrieg strike force.

Commanded by Generalmajor Wolfram Freiherr von Richthofen, a cousin of the legendary Red Baron of World War One, the Fliegerführer zbV comprised four Stukagruppen (totalling over 150 Ju 87s), and a Gruppe each of Hs 123 ground-attack biplanes, twin-engined Bf 110 Zerstörer and Bf 109 single-seat fighters. Based in Upper Silesia, its task was first to smash a path through the Polish frontier defences and then support the Panzer divisions of the 10th Army as they fanned out in a twin-pronged advance north-eastwards towards Warsaw.

From a hill overlooking the river that marked the Silesian-Polish border von Richthofen watched the exhaust flames of his 40 Hs 123s as they took off in the pre-dawn darkness of September 1 to attack Polish army positions on the far bank. Meanwhile, overhead, the Stukas were setting out on pre-emptive strikes on the enemy's forward airfields. Such raids, designed to knock out the opponent's air power, would be an integral part of all future Blitzkrieg campaigns. But in Poland the tactic was not entirely successful.

FIRST BLOOD

Aware of the looming threat, many Polish air force units had already vacated their permanent bases and were deployed on outlying landing grounds. It was while returning from their initial raid on a near-deserted Krakow airfield that one of the Stukagruppen, I./StG 2 'Immelmann', chanced to overfly one of these satellite airstrips just as a pair of Polish PZL P.11c fighters were on the point

Bf 109Es of Jagdgruppe 102 (I./ZG 2), the most successful fighter unit in Poland with 28 enemy aircraft shot down and nearly 50 destroyed on the ground. (All photos author unless stated)


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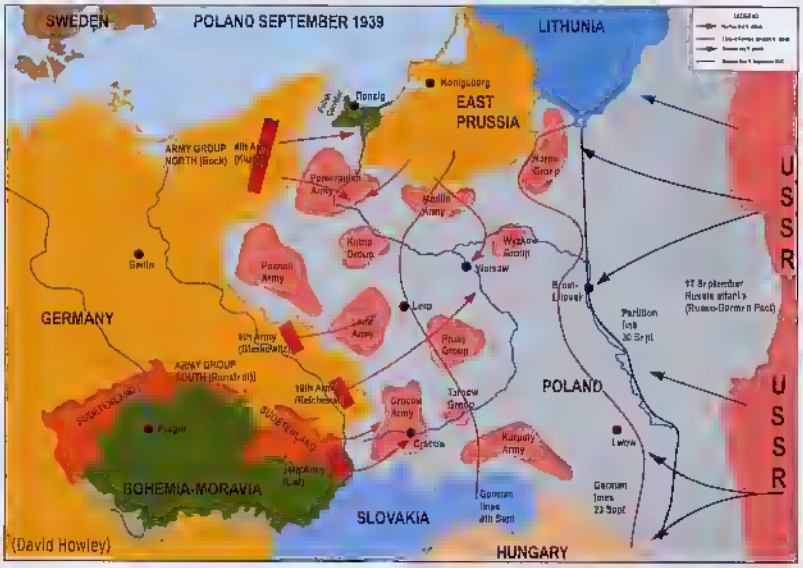
Two-blade Bf 109Ds pictured on the eve of war. Some, if not all, of these machines belong to JGr 102 (II./ZG 1) – note those in the background with large white circles below the windscreen: this is the unit's 'Hunter of Barnburg' emblem. (Bundesarchiv BA Bild101I-379-0015-18)

This unidentified Luftwaffe Leutnant standing on the wing of a downed Polish PZL P.23B Karas – light reconnaissance bomber has presumably 'borrowed' his unit's Fi 156 runabout (background) to visit the scene of his recent success.

of taking off. Although still clawing for height, the first Pole latched on to the tail of a passing Stuka, unaware that another three Ju 87s were coming up fast behind him. The leader of the second Kette let fly with his two 7.9mm wing machine-guns. The hapless PZL "suddenly exploded in mid-air, bursting apart like a huge fireball – the fragments literally flew around our ears". The speaker, Stuka pilot Leutnant Frank Neubert, had just claimed the first aerial victory of World War Two!



Although the Polish Air Force was not crippled at the outset, but continued to fight gallantly throughout the campaign, nothing could halt the German advance. Quickly gaining momentum, the leading Panzers of 10th Army were across the River Warthe, the only major water barrier guarding the south-western approach route to Warsaw, within 24 hours. There were a few mishaps while the German ground and air forces were getting used to the close collaboration demanded by the Blitzkrieg concept. In one or two instances army commanders failed to call for air support when it could have been used to advantage. After the right wing of the 10th Army encircled six Polish divisions to the SE of Radom however, it was the pounding by von Richthofen's Stukas, perhaps more than anything else, that persuaded them to surrender.

But it was the three dozen Hs 123 ground-attack biplanes of II.(Schl)/LG 2 that proved to be the surprise success story of the Polish campaign. Flying only feet above the heads of enemy troops and horse-drawn columns – bombing and machine-gunning as they went – the elderly Henschels created panic among man and beast alike. These same Hs 123s were also supporting the leading elements of the 4th Panzer Division when they reached the outskirts of Warsaw in the early afternoon of September 8.

It was at this juncture that the Germans faced their only major crisis of the campaign. West of the capital the still largely intact Polish Poznan Army suddenly launched a counter-attack on the infantry divisions of the German 8th Army securing the 10th's left flank. The latter's Panzers, already closing in on Warsaw, were in danger of being cut off. Answering the army's desperate appeals for help, the Luftwaffe threw in everything it had. A week-long bombardment, culminating in continuous attacks by the Ju 87s and Hs 123s throughout the daylight hours of September 16 and 17, finally forced the survivors of the Poznan Army to lay down their arms – 170,000 prisoners were taken.

Towards the end of the Polish campaign, the Stukas of III./StG 2 'Immelmann' were transferred down from the Baltic area to Slovakia to prevent the last remnants of the Polish Army escaping southwards into Hungary or Romania.

Concept Proved

Back in Germany the invasion of Poland was soon being hailed as the 'Eighteen day campaign'. And while it is true that most resistance in the field had ended after 18 days, many Polish strongpoints – and the nation's capital – continued to hold out. Von Richthofen's units remained in action until the end, bombing Warsaw and the

Modlin forts until Poland's official capitulation on September 27.

The 'lightning war' against the Poles hit a Europe that was still steeped in memories of Flanders' mud, and advances measured in yards, like a thunderbolt. It made the reputations of the Ju 87 Stuka and the Bf 109 Zerstörer heavy fighter as the new 'wonder weapons of the age'. It also produced World War Two's first fighter ace. JGr 102, von Richthoten's sole single-seat fighter escort Gruppe, was, in reality, a Zerstörer unit (I./ZG 2) flying obsolescent Bf 109Ds while awaiting delivery of its twin-engine Bf 110s. Nevertheless, the four Polish PZL P.23 light bombers claimed by the Gruppe CO, Hauptmann Johannes Gentzen, south of Brody on September 14 had taken his total number of victories to seven, thereby making him the highest scorer of the campaign.

Members of an unidentified Bf 109 fighter unit examine the remains of an Armée de l'Air Curtiss Hawk 75, one of the previous occupants of the base that they briefly occupied during their advance through France

Ju 52s at the time of the Polish campaign. Used mainly as transports, they also served as auxiliary bombers. (Bundesarchiv BA Bild101I-317-0053-18)

'Black men' – Luftwaffe parlance for ground crews on account of the black overalls they wore – refuel a Bf 109E of III./JG 2 'Richthoten' in readiness for the next mission.

The 30-week 'Phoney War' in the West, which followed the defeat of Poland, was utilized by the Luftwaffe to increase its front-line strength by almost 50% (from 67 Gruppen to 96). Generalmajor von Richthofen's 'special purposes' command was elevated to the status of an air corps (VIII.Fliegerkorps). His number of Stukagruppen was raised to six and Hauptmann Gentzen's departed JGr 102 – having re-equipped in the meantime with their long-awaited Bf 110s – had been replaced by three full Jagdgruppen of Bf 109Es. A force of over 100 Do 17Z bombers had also been temporarily attached to the corps to give it additional reach.

Attack West

It was in this revised and strengthened form that von Richthoten's units took their place alongside the two other corps that made up Luftflotte 2, the air fleet making up the northern flank of the forces gathering to invade France and the Low Countries. That invasion, launched at dawn on May 10, 1940, began with bombing raids on at least 70 airfields in France, Belgium and Holland.

But a new dimension had been added to the Blitzkrieg in the west: the use of airborne troops to neutralize the defences and secure those river crossings in the Low Countries vital to the success of operations on the northern flank. The hardest nut of all to crack was the 'impregnable' Belgian fortress of Eben Emael, built into the near-vertical sides of the Albert Canal – itself, in effect, an enormous 125-foot deep anti-tank ditch – close to the Dutch border. While the fortress was taken out by glider forces actually landing on top

Kette (formation of three aircraft) of Ju 87B Stukas lifts off, each machine carrying a single 500kg bomb under the fuselage. (Bundesarchiv BA Bild101I-318-0053-35)

Paratroops dropping from Ju 52s. The Germans used this technique to good effect during the invasion of Holland in May 1940.

Bf 110s of III./ZG 76 - the famous 'Sharksmouth' Gruppe - probably pictured around the time of the Battle of France. (Bundesarchiv BA Bild101I-382-0211-22)

Having moved forward into Belgium, a Ju 87B of StG 77 takes a breather flanked by the wreckage of a pair of Belgian AF Fiat C.R.42 biplane fighters - the latter either destroyed in an air attack, or blown up and abandoned during the retreat.

of If, the Ju 87s and Hs 123s of VIII.Fliegerkorps supported the troops assaulting the river and canal bridges close by. By the day's end, each of von Richthofen's units had flown some 8-10 separate missions and the Panzers of 6th Army, the water barriers safely behind them, were beginning to push westwards into Belgium.

The Allied response was predictable. Fearing a repeat of the 1914 offensive which had seen the German Army drive into France via the neutral Low Countries, the French and British troops stationed along the Franco-Belgian border now left their prepared positions and raced forward to meet the advancing enemy head-on ... which is exactly what the German High Command had wanted them to do!

For while the airborne operations and subsequent rampaging of Army Group B's three Panzer divisions in the north had been grabbing all the attention, the real strike force of the German offensive in the west - the 7 Panzer and 4 motorized divisions of Army Group A - had been biding their time hidden in the wooded valleys of the Eifel hills down near Luxemburg. Rather than copying the tactics of 1914, the 1940 campaign was standing them on their head. The advance through the Low Countries had been an elaborate feint. The main attack would be launched in the south; a gigantic Sichelschnitt (scythe-cut) armoured sweep aimed at the Channel coast through that part of NE France largely vacated by the British and French when they hastened forward to the aid of the Belgians.

But before the Panzers of 12th Army spearheading the southern assault could begin charging across the rolling plains of Picardy they too had one major water obstacle to cross: the River Meuse. Brushing aside local resistance in the Ardennes, the leading Panzers reached the river at Sedan on the evening of May 12.

Their tasks in the north completed, von Richthofen's Stukas were rushed southwards to support the crossings the following day. In just one five-hour period during that May 13, StG 77 alone flew more than 200 individual sorties against the French positions guarding the river line. Unable to withstand this kind of onslaught the demoralized defenders broke. Within 48 hours the Meuse had been successfully breached, the Panzers were across, and the way to the Channel lay open.

Realizing the danger, Allied bombers attacked the German bridgeheads throughout May 14. But it was too late. That date went down in Luftwaffe history as the 'Day of the Fighters'. By its end the wreckage of 89 British and French bombers littered the Meuse valley. But the three Bf 109 Gruppen of VIII.Fliegerkorps had not claimed a single one of those victories. They were fully committed to escorting the corps' close-support units which were already operating well to the west of the river blasting a path for the Panzers' advance to the coast.

On May 20 spearheads of 2nd Panzer Division reached the English Channel north of Abbéville. The Allied troops in the northeast - British, French and Belgian (the Dutch had capitulated on May 14) - were thus effectively cut off from the main body of the French army. Having successfully supported 12th Army in its headlong dash to the sea, von Richthofen now divided his forces. He ordered some of his Stukagruppen to attack the Channel ports of Boulogne and Calais. The remainder, together with the Hs 123s

of II.(Schl)/LG 2, he directed against the Allied troops beginning to fall back on Dunkirk.

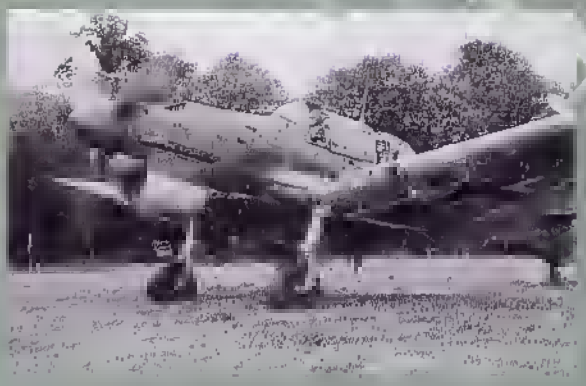
After heavy bombardment Boulogne was captured on May 23, and Calais four days later. By this time the withdrawal from Dunkirk was under way. While the Henschels continued to harass the rearguard parties holding the inland perimeter of the shrinking Dunkirk pocket, the Stukas turned their full attention on to the evacuation beaches and the offshore shipping.

Long before the last Allied soldier had been lifted off, however, VIII.Fliegerkorps had been withdrawn from the Channel coast. Its ground-support expertise was needed for the second and final phase of the battle for France – the defeat of the major part of the French army still largely intact and unengaged to the south. Von Richthofen's Stukas were tasked firstly with supporting the crossing of the Somme and then the breaching of the Weygand line around Laon. After that they were to cover the 2nd Army's advance southwards to the Swiss border.

Launched on June 5, the last two weeks of the Stukas' campaign in France consisted of little more than harrying the enemy's forces from one natural river barrier to the next as the French retreat gathered momentum. Once over the Somme, the Germans next crossed the Marne near Château-Thierry to the east of Paris on June 12. Twenty-four hours later the French capital was declared an open city. June 17 found the Stukas attacking enemy columns around Dijon and supporting bridgeheads over the Loire near Nevers. It was on this date that French Marshal Pétain appealed for an armistice.

The following day Generalmajor von Richthofen ordered two-thirds of his units to stand down. By June 19 VIII.Fliegerkorps was being held at readiness in the Nevers-Auxerre area of central France, but the next day's scheduled mission was cancelled and all further advances halted.

On June 22 France signed the armistice with Germany. The nation that had held out against the German invader for four long years between 1914 and 1918 had been beaten in just 44 days. Blitzkrieg, it seemed, was unstoppable! ■



At the end of the French campaign, a shrapnel- and bullet-riddled Ju 87 Stuka of StG 2 prepares to take off back to Germany for some very necessary repair work

Heinkel He 111s taxi out at a French airfield during the Battle of France. (Bundesarchiv BA Bild101I-401-0540-20)

A heavily retouched propaganda shot of 8f 110s of V.(Z)/LG 1 flying over Paris after the French surrender. Note the Arc de Triomphe bottom left

A Messerschmitt Bf 109G arrives back at its German base following another sortie, most likely against American daylight bombers – the year is believed to be 1943.
(Bundesarchiv BABild(011-649-5355-02)

SPECIFICATION

Bf 109G

Wingspan	32ft 6½in (9.92m)
Length	29ft 7in (9.02m)
Height	11ft 2in (3.40m)
Gross Weight	6,945lb (3,150kg)
Max Speed	386mph (621km/h)
Service Ceiling	38,550ft (11,750m)
Range	447 miles (720km)
Armament	3 x 20mm cannon & 2 x 13mm machine guns
Powerplant	1 x DB 605 AM

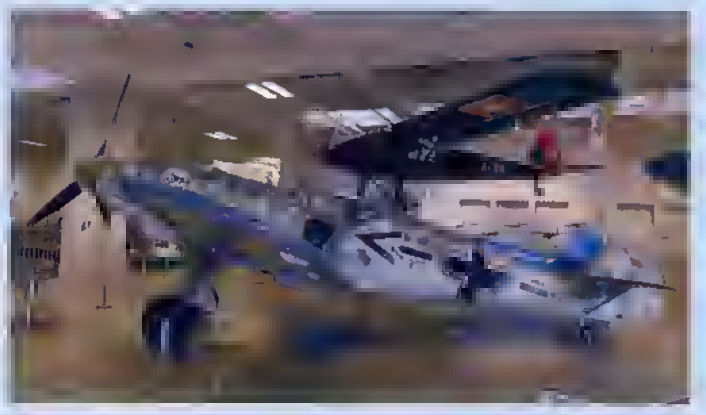
As Germany secretly began to rearm its military during the 1930s, designer Willy Messerschmitt came up with a number of aircraft to meet the needs of the Luftwaffe. Probably his most famous creation was the Bf 109 which has the distinction of being produced in the highest number of any fighter aircraft in history – in excess of 35,000 examples.

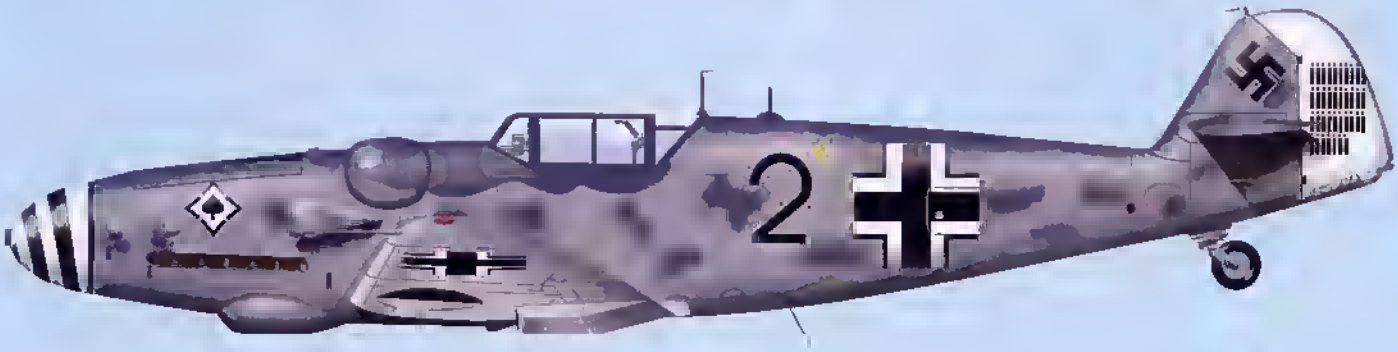
The prototype made its maiden flight on May 28, 1935, and interestingly was powered by a British Rolls-Royce Kestrel engine. In subsequent prototype aircraft and the first production Bf 109Bs, various marks of the indigenous Jumo 210 were used. From the Bf 109D onwards variants of the Daimler-Benz DB600 engine were employed. The first production aircraft were delivered to JG 132 in early 1937 and the type first saw action during the Spanish Civil War.

By the time Germany invaded Poland in September 1939, the Luftwaffe had in excess of 1,000 Bf 109s at its disposal. The '109 was the Luftwaffe's primary fighter aircraft of the period and it played a major part during the Battle of Britain in the summer of 1940. Its lack of range severely hampered its effectiveness while operating from airfields in northern France, but despite this it still inflicted heavy casualties on the RAF during the battle. By this time construction had been scaled back to around 156 examples per month, but as Germany turned its attention to Russia in 1941 and then went on the defensive in Western Europe during 1942, so production rates skyrocketed.

The Bf 109's cockpit was a little more confined than that found in the Spitfire but the most obvious disadvantage facing pilots of early models was lack of visibility caused by the heavy framing applied to the original cockpit canopies. (KEY · Steve Fletcher)

This Bf 109E is preserved in the Deutsches Museum in Munich and is thought to be the oldest surviving E model, dating back to before the war. (KEY · Duncan Cubitt)





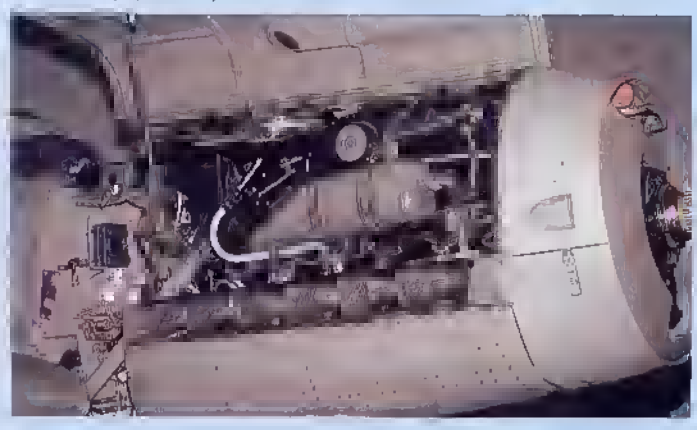
Messerschmitt Bf 109G-6 of 5./JG 53 based in Sicily. (Pete West)

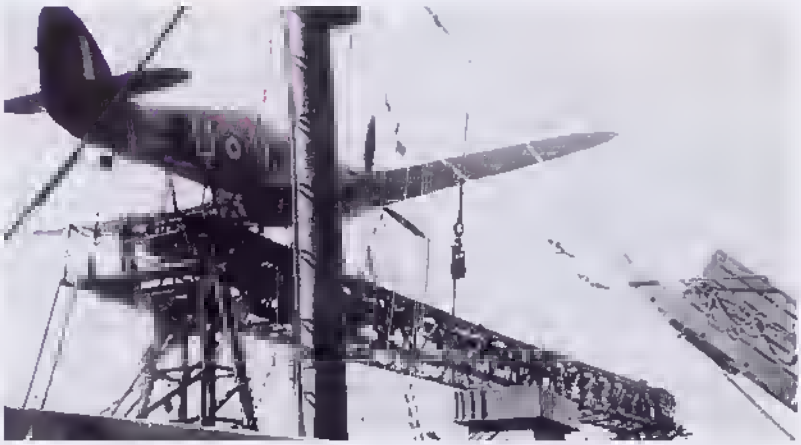
The aircraft was built in a number of marks, chiefly the E, F and G models, although these included a whole series of sub-variants. Armament usually included a 20 or 30mm cannon firing through the propeller hub, as well as machine-guns in the top of the nose firing through the propeller and either more machine-guns or cannon in the wings.

In the hands of a good pilot, the Bf 109 could hold its own against most Allied fighters but the arrival of aircraft like the American P-51 Mustang and the British Hawker Tempest in 1944 led to it being generally outclassed. Its use of a narrow track undercarriage made it very susceptible to handling problems on rough ground and it was quite a tricky aircraft to land, especially for an inexperienced young pilot.

Its operational record is impressive as it served the Luftwaffe on all fronts right through to the end of the war and remains an iconic example of German efficiency.

The Daimler-Benz DB 605 fuel-injected engine was an inverted vee-12 design which, unlike the early carburettor-equipped British Merlins, was not prone to cutting out during negative-g manoeuvres. (KEY collection)





In a bid to counter the Fw 200 and other air threats, catapults were fitted to a number of vessels so that a Hurricane fighter could be launched to defend the convoy. The only drawback was that the aircraft could not be recovered and had to ditch, hopefully near to the convoy so that the pilot could be rescued. (Andrew Thomas collection)

After the war Britain's Prime Minister Winston Churchill famously said: "The Battle of the Atlantic was the only thing that really frightened me." His fears were justified, because had the German U-boats won, Britain's supply lifeline would have been cut, making it impossible to continue the fight.

The vulnerability of this shipping lifeline was exposed on the very first day of the war when the passenger vessel SS *Athenia*, was sunk by the U-30. Although shipping in coastal waters was at risk of U-boat attack, it was the international supply lines in the wide open expanse of the Atlantic Ocean that needed greater protection from the menace beneath the waves. As the war progressed, aircraft were to play an increasingly important role in defeating the U-boats.

Early steps

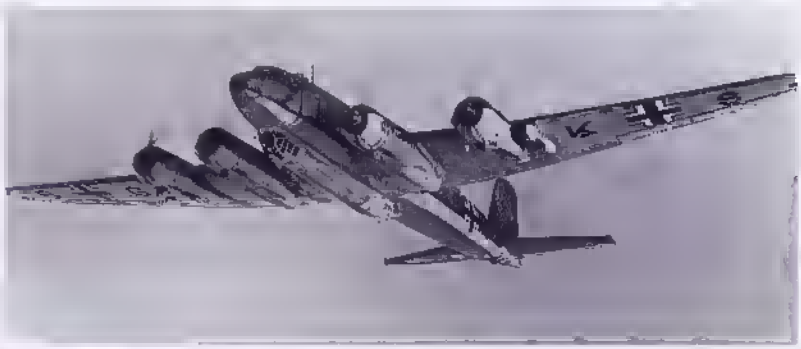
For the first few months of the war the Germans only had a few U-boats deployed in the Atlantic, it was not until France fell in the summer of 1940 that Germany was able to base submarines at ports on the west coast of France and therefore expand its operations in the Atlantic. Initially the Royal Navy and RAF Coastal Command fought what were essentially separate battles against the submarine menace, though co-operation between them improved fairly rapidly.

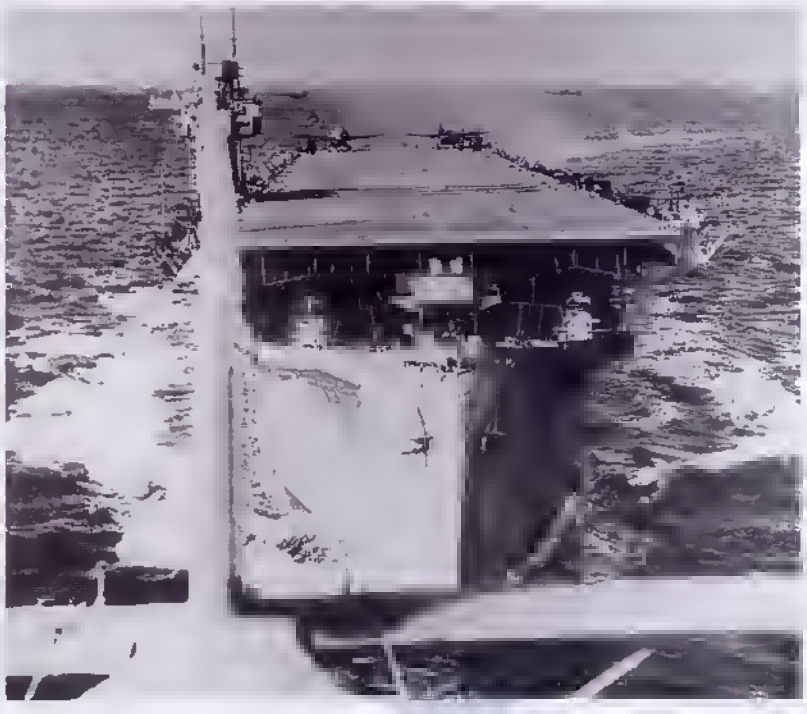
The German surface fleet was numerically inferior to the British Royal Navy and its allies - the loss of the battleship *Bismarck* in 1941 bearing testament to this. Consequently, its submarines - under the leadership of Admiral Karl Dönitz - provided the most efficient means of countering the British supply convoys. And so it fell to the U-boats to go on the offensive, and for the first two years of the war they went about this task in a ruthless fashion.

In 1940 and even into 1941 Coastal Command's resources were woefully inadequate in terms of combating the U-boat menace. Long-range flying-boats, such as the Short Sunderland, were in short supply and better weapons had to be perfected in order to assure damaging a submerged U-boat, but from August 1940 an air-dropped depth charge did improve things for the Allies. Finding a U-boat in the vast expanse of the Atlantic was an altogether more complex operation.

The British intelligence agencies played a crucial role and, in particular, the code-breakers at Bletchley Park worked hard to crack the seemingly impregnable Enigma cipher used by the Germany Navy. In the meantime, experiments with early forms of air-to-surface radar (ASV) began in early 1940 (see pages 66-71) in an attempt to detect submarines on the surface. Even so in 1940 more than 1,000 Allied ships were sunk and this rose to 1,299 ships the following year, outstripping the rate at which they could be replaced. The supply line was bleeding dry.

Below: Even Tiger Moths were hastily employed on 'scarecrow' CPF duties, this example belonged to 217 Squadron based at Caraw Charlton, southwest Wales, in early 1940. (Andrew Thomas collection)





Above right: An early threat to Atlantic convoys was the Fw 200 Condor, which not only attacked the convoys but also shadowed them in order to radio their locations to nearby U-boats. (KEY collection)

HMS *Biter* - a typical escort carrier, which was equipped with Swordfish and Martlets in 1943. (Andrew Thomas collection)

The air threat

Convoys were not only at the mercy of the submarine, the Luftwaffe used long-range bombers, in particular the Focke-Wulf Fw 200 Condor, to locate, shadow and attack convoys deep into the middle of the Atlantic. Some form of convoy defence fighter was needed, and because aircraft carriers were in such short supply in 1940/41 an ingenious solution would have to be found. And it was - several vessels were modified with a catapult rail system to launch a Hurricane fighter that could then defend the convoy from air attack. But there was a drawback - it was impossible to recover the aircraft after it had been launched and so the pilot had to ditch in

THE BATTLE OF THE ATLANTIC

Winning the Battle of the Atlantic was vital for Britain's survival. As Mark Nicholls highlights, aircraft played an increasingly pivotal role in its outcome.

The scourge of the Allies' Atlantic convoys – the German U-boat. (Andrew Thomas collection)

the sea and, hopefully, be rescued. While this might seem like a drastic measure, it was quite effective and did deter Fw 200s from harassing the convoys as much, although they continued reconnaissance missions and passed convoy locations and headings to the U-boats.

Once America entered the war in December 1941 the size and number of convoys increased as every effort was made to keep Britain supplied with food, raw materials and munitions. However, the British had introduced a new type of ship at the beginning of 1941 to assist in convoy protection, the escort carrier. The first of these was HMS *Audacity*, which was launched on January 22. The early escort carriers were usually converted from merchant ships and were much smaller than the fleet's main aircraft carriers. But they were cheaper and easier to produce, and even more so once America started to produce its own versions later in 1942. Among the initial aircraft employed were the Grumman F4F Wildcat and the TBM Avenger torpedo bomber.

Later in the war a Casablanca class vessel, the USS *Guadalcanal* (CVE 60), achieved a major claim to fame by becoming the only escort carrier to capture an intact U-boat, the U-505

Coastal Command

In the first two years of the war RAF Coastal Command was severely stretched trying to give adequate air cover to convoys in the southwest approaches and off northwest Scotland, let alone further out in the Atlantic. Operating Fleet Air Arm aircraft from large fleet carriers was not a great success initially and indeed the use of these carriers made them vulnerable and resulted in the loss of HMS *Courageous* to the U-29 on September 17, 1939. Every conceivable aircraft was also brought in to help, such as Stranraer, London and Sunderland flying-boats, Hudsons and even Tiger Moths! The latter equipped land-based Coastal Patrol Flights (CPFs) in an effort to spot U-boats around Britain, although they were not very effective.

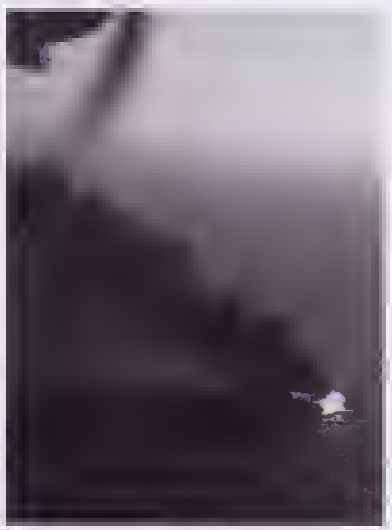
In addition to British aircraft, American PBY-5 Catalinas and Liberators eventually joined the battle during 1941 and their long-range was to prove invaluable. It was not until the authorities realised the scale of the threat that they were facing that orders were given to strengthen Coastal Command's assets but gradually during 1941 more aircraft became available and so did improved versions of ASV radar. Another vital piece of equipment, which became available in 1942, was the Leigh Light, a powerful spotlight that could be used in conjunction with the improving ASV radar to detect surfaced U-boats at night.

Raising the tempo

The Germans increased the intensity of their operations in March 1941 in the hope of completely severing the convoy supply routes. To counter this, more attacks were made on U-boat facilities, such as their pens and construction yards. However, Admiral Dönitz had released a large number of new U-boats into the Atlantic and Allied shipping losses started to increase alarmingly.

As the months passed so the Germans began to adopt new tactics – one such was the Wolf Pack, a large group of U-boats that would stalk and attack a convoy, often in the middle of the Atlantic (known as the Atlantic Gap) well beyond the reach of Allied air patrols. The arrival of the long-range Liberator eventually helped to plug this gap and with the assistance of aircraft flying from Canada – and America once it had entered the war – the entire convoy route could be covered.

Even so, by the end of 1941 there were around 200 U-boats available, mostly attacking at night,



The price paid by the merchant seamen was a high one – another tanker goes down after being torpedoed by a U-boat. (Andrew Thomas collection)

Below: More destructive depth charges, both air dropped and ship launched, were the primary weapons used against the U-boats. They were particularly deadly, and not surprisingly their use terrified submarine crews. (Andrew Thomas collection)

Right: The Consolidated PBY-5 Catalina certainly improved in patrol range – not only to look for U-boats but also surface raiders. This aircraft, Catalina I AH545/'WQ-Z' of No.209 Squadron was responsible for spotting the *Bismarck* at 10.30 hours on May 26, 1941, while the battleship was still 690 miles (1,110km) northwest of Brest. (Andrew Thomas collection)

and shipping losses continued to rise. It's worth mentioning that although America did not enter the conflict until December 7, 1941, on September 11th of that year, the US Government authorised its forces to attack any Axis vessel found to be endangering convoys. The British warned America that U-boats posed a significant threat to shipping in its coastal waters, but sadly the US Navy and US government authorities failed to take sufficient precautions, with the result that in early 1942 the Germans inflicted heavy losses on American ships that were often sailing alone and fully lit at night!

Despite improved equipment Coastal Command had by mid-1941 destroyed relatively few U-boats. However, this growing and more capable airborne force did act as a deterrent and had a greater impact on the enemy's tactics than is often acknowledged. When a convoy was given almost continuous air cover during its crossing, losses to U-boats were minimal, but if this was interrupted for some reason, probably due to bad weather, it was a very different story.

By early 1942 Admiral Dönitz had also introduced a tanker U-boat (called the 'milch [milk] cow') which could refuel, re-arm and re-supply his long-range U-boats at sea. This gave them considerably longer on-station, in particular in the Atlantic off Florida and in the Caribbean area where they could target oil tankers.

Having learned valuable but costly lessons, the Americans took advice and assistance from their Allies. A more co-ordinated system was put in place to protect the convoys, and when combined with better air cover, losses gradually declined in American coastal waters.

A 269 Squadron Hudson III seen on patrol from Iceland in 1941. This squadron was the only one to 'capture' a U-boat when the U-570 surrendered to an attacking crew on August 27, 1941. (Andrew Thomas collection)

Turning the tide

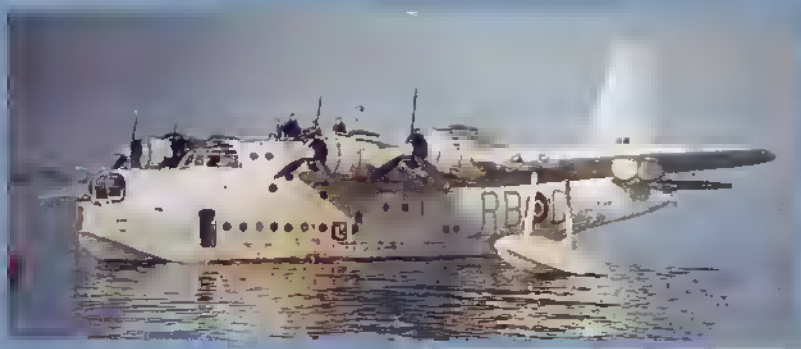
On the eastern side of the Atlantic Air Marshal Sir Philip Joubert de la Ferte, AOC-in-C Coastal Command, had studied the complex U-boat problem and devised new tactics in an effort to get the upper hand. It was noticeable that as U-boats crossed the Bay of Biscay from the French ports to the mid-Atlantic they had to spend a certain amount of time on the surface to recharge their batteries and ventilate the interior. As they had to cross a specific area, it seemed logical that the best move would be to concentrate more patrols here than endlessly searching the wider Atlantic.

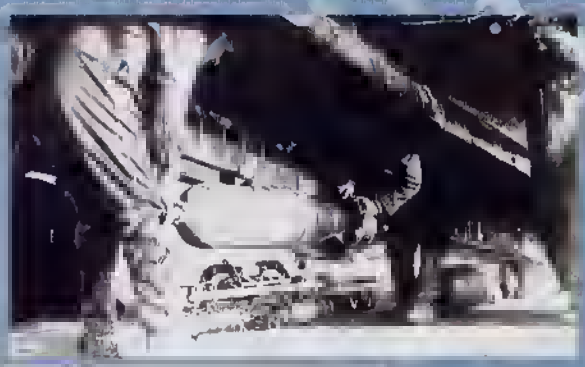
This proved to be an effective strategy, especially as aircraft now had better ASV radar and Leigh Lights. From December 1942 the Bletchley Park code breakers were making great headway in cracking the Enigma code, thus making it possible to decipher more of the German transmissions. It was becoming easier to track and counter the Wolf Packs and more importantly the 'milch cows', or divert the convoys to avoid the threat. In reply, Germany developed a radar detection device called Metox and soon U-boat sightings in the Bay of Biscay fell dramatically. The Allies responded by introducing the 10cm wavelength ASV III.

Despite the efforts of the Allies, the first few months of 1943 proved to be very costly as the Germans managed to intercept several convoys in the Atlantic Gap. This led to intervention from American President Theodore Roosevelt who decreed that more very long range Liberators should be made available to RAF Coastal Command. Furthermore in May 1943 the RAF introduced the 'Fido' acoustic homing torpedo, a new weapon that enabled aircraft to attack submarines even after they had 'gone deep' to avoid depth charges. Overall the month of May certainly did prove to be

Coastal Command received the surviving RAF Fortress I aircraft from Bomber Command in early 1942, this 220 Squadron example is seen over a convoy in mid-1942. (Andrew Thomas collection)

Whitley VII Z6633/'WL-G' of No.612 Squadron shows off its ASV Mk.I aerials in the spring of 1941. (Andrew Thomas collection)





a bad one for the U-boats with 41 being destroyed, 23 of them by Allied aircraft.

As the summer of 1943 passed so both sides varied their tactics. The Germans grouped their submarines while transiting the Biscay area so that their combined firepower could fend off air attacks. In response, Coastal Command began to patrol with sweeps of aircraft instead of individual search patterns. The net result was an increasing number of U-boats destroyed or damaged, while attacks on convoys were reduced.

The autumn of 1943 was just as expensive for the Germans as they attempted to continue Wolf Pack operations in the Atlantic – 20 U-boats were sunk in October alone. Significantly British aircraft began operations from the Azores in October, following rapid negotiations with the Portuguese, thus giving them a base much closer to the central Atlantic. German losses continued to mount into 1944 and in the first three months of that year, 60 U-boats were destroyed.

Although German U-boat operations continued for the remainder of the war, they were usually limited to individual patrols – the larger Wolf Pack had become too easy to find and attack.

Following the D-Day landings in Normandy on June 6, 1944, the Americans promptly captured the French ports in the Bay of Biscay, thus denying the U-boats their primary bases and forcing them back to their homeland bases or those in Norway. Up until then the Germans had been making good use of a snorkel device which enabled them to run submerged on their diesel engines and were thus much more difficult to detect. But the introduction of the 3cm ASV X radar in the autumn of 1944 meant that the snorkel or even a periscope could now be detected, and so the submariners again found it hard to hide.

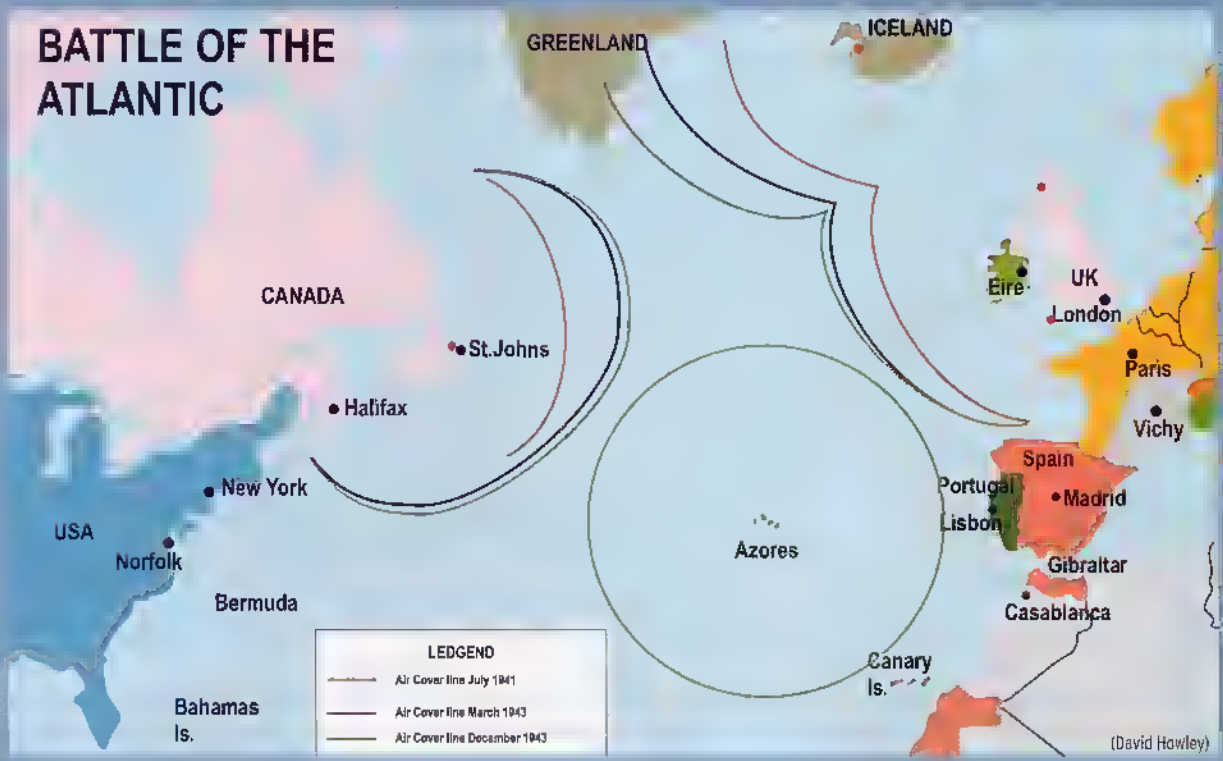
By the end of the war Coastal Command, together with the USAAF and US Navy units under its control, had sunk 207 U-boats – this combined with losses inflicted by naval vessels had won the Battle of the Atlantic, but it was a perilously close-fought encounter. ■

Above: A 524 Sqn Wellington GR.XIV is loaded with flares and depth charges at Langham in early 1945. (Andrew Thomas collection)

Top left: The Sunderland was one of the most capable of all Coastal Command's aircraft – it had a good range and was able to put up a spirited fight against both U-boats and enemy fighters. (Andrew Thomas collection)

Above left: A Wellington GR.XIV of No.172 Squadron with the Leigh Light in the down position. The squadron pioneered Leigh Light use, considerably improving the night-time destruction of U-boats. (Andrew Thomas collection)

Left: The U-625 goes down on March 10, 1944, after it was attacked by 422 Squadron Sunderland EX591. In this case a number of survivors can be seen, however more often than not, U-boats were destroyed beneath the surface by depth charges and so escape was impossible. (Andrew Thomas collection)

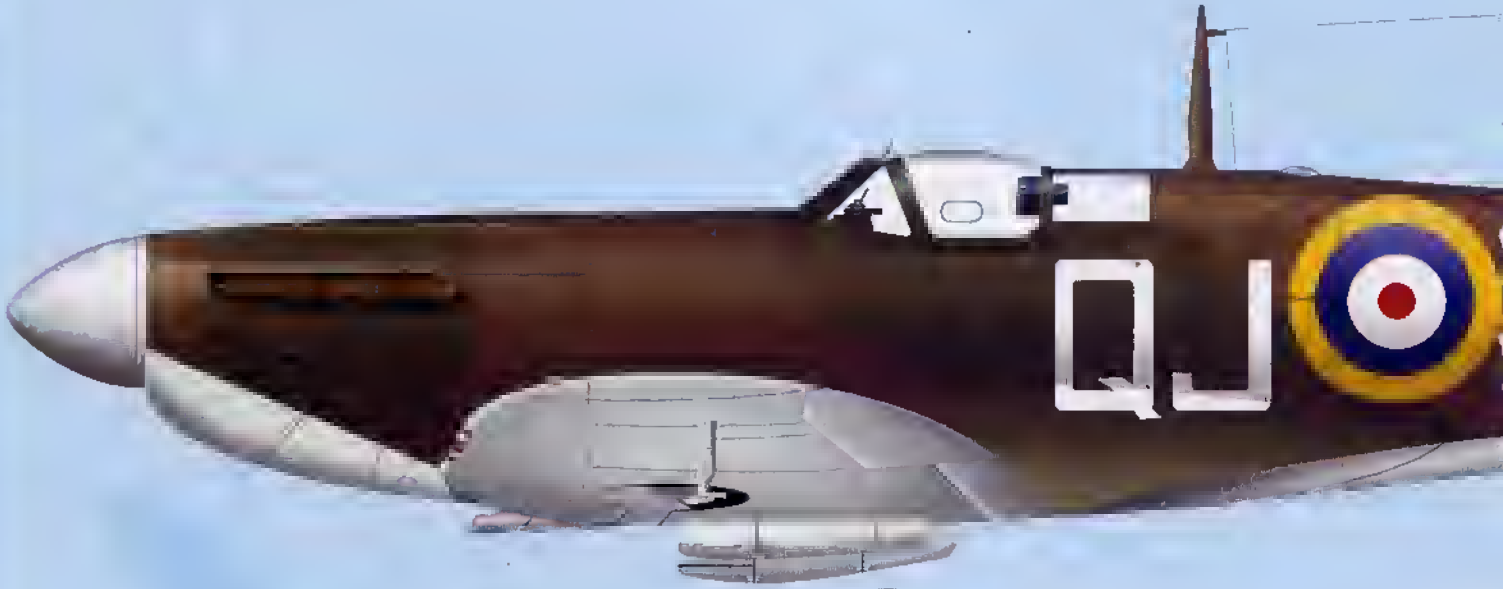


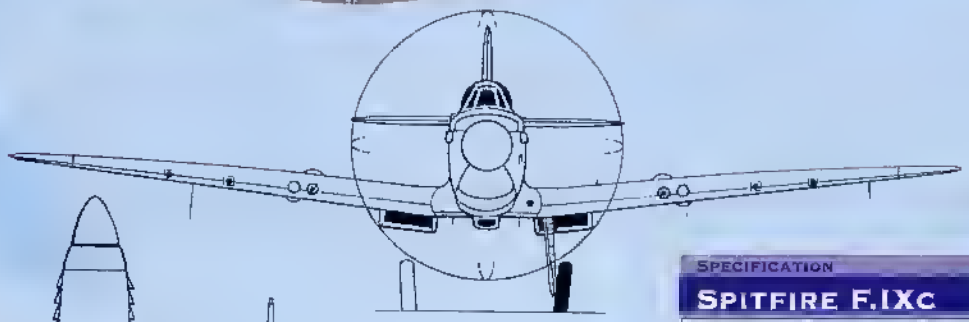
The legendary Spitfire is widely regarded as one of the most successful piston-engine fighters ever built. Designed by R J Mitchell to meet Air Ministry Specification F.37/34 for a fast monoplane fighter, it easily fulfilled the requirement when the prototype first flew on March 5, 1936. The Spitfire is famed for the part it played during in the Battle of Britain, but the type was subsequently developed through an extensive series of marks – it was even adapted for use on the Royal Navy's aircraft carriers, and in this guise was known as the Seafire.

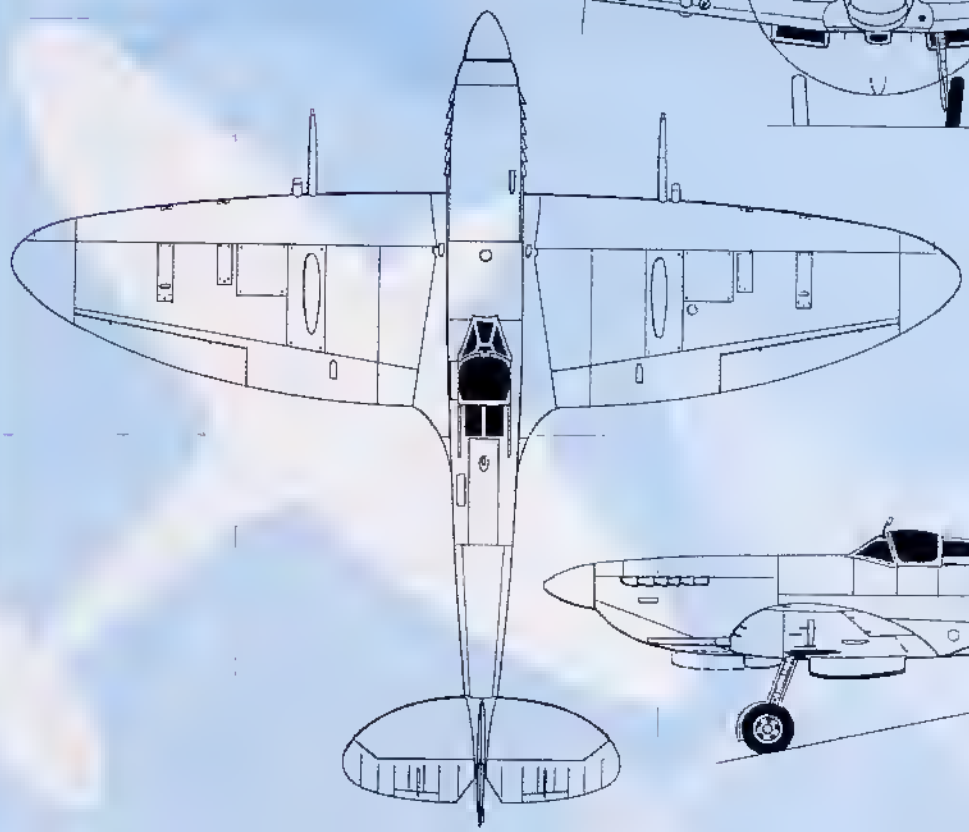
The original version was armed with eight .303 Browning machine-guns but later marks were fitted with 0.5in machine-guns and 20mm cannon in place of the .303s. Most Spitfires were powered by the Rolls-Royce Merlin engine, though as time passed more powerful versions of the famous powerplant were fitted. The Mk.XII and Mk.XIV introduced the Rolls-Royce Griffon which produced more than double the power of the early Merlin engines.

Although these later marks, which appeared in the final couple of years of the war, retained the distinctive elliptical wing shape of the original, they were practically a new aircraft in terms of performance.

As well as being a superb fighter, the Spitfire was also used in the photo-reconnaissance and fighter-bomber roles. It remained in front-line service in all theatres throughout the war and for several afterwards, before finally being retired by the RAF on April 1, 1954. Total production of Spitfires and Seafires exceeded 22,000, easily making it the most numerous British fighter in history.





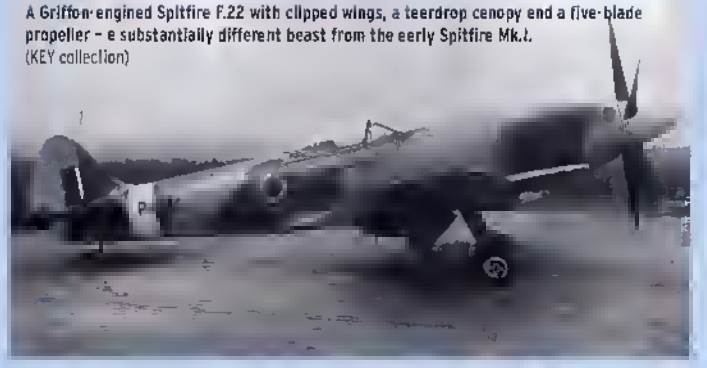


SPECIFICATION

SPITFIRE F.IXC

Wingspan	36ft 10in (11.23m)
Length	31ft 3½in (9.54m)
Height	11ft 8in (3.56m)
Gross Weight	7,300lb (3,311kg)
Max Speed	408mph (657km/h)
Service Ceiling	40,000ft (12,192m)
Range	434 miles (698km)
Armament	2 x 0.5in machine-guns & 2 x 20mm cannon
Powerplant	1 x Merlin 61 or 63

A Griffon-engined Spitfire F.22 with clipped wings, a teardrop canopy and a five-blade propeller – a substantially different beast from the early Spitfire Mk.I.
(KEY collection)



Spitfire IIa P7753 of 616 Squadron. (Pete West)

The Spitfire's cockpit was compact but functional, and offered a much better view whilst airborne than was available to the pilot of its primary opponent, the Messerschmitt Bf 109.
(KEY - Duncan Cubitt)

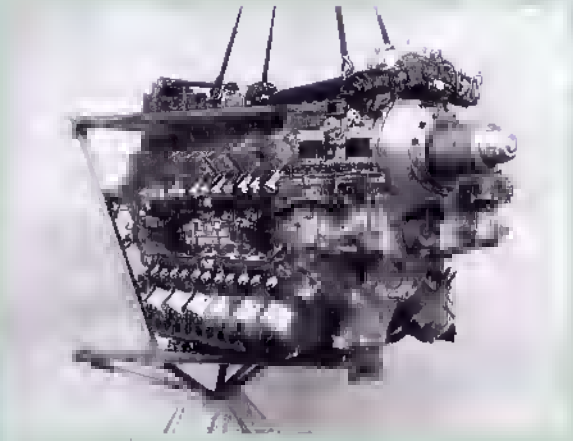
The high nose and classic bubble canopy are two of the Spitfire's most distinctive features. A joy to fly, it was and still is held in the highest regard by all those who have flown it. The aircraft's nose obstructed forward vision whilst taxiing on the ground, which meant the pilot had to weave about whilst looking out of the sides of the cockpit... but that aside, the Spitfire had no vices. (KEY - Duncan Cubitt)

ENGINES

THE DRIVING FORCE OF WORLD WAR TWO

Radial engines proved popular with the US Navy and Marine Corps as they were less complicated than liquid-cooled types and safer for carrier operations. The Vought F4U Corsair and its massive propeller was one of the most significant aircraft to fight in the Pacific Theatre. (Key - Duncan Cubitt)

BILL GUNSTON, OBE, FRAeS, EXAMINES THE MULTITUDE OF DIFFERENT ENGINES THAT POWERED THE AIRCRAFT OF WORLD WAR TWO.



Above: The air-cooled sleeve-valve Rolls-Royce Exe would have been a better engine than the Merlin and Griffon for British naval aircraft, such as the Barracuda and Firefly, but it was cancelled in a prime example of short-sighted government bureaucracy. (Author)

Above left: Rolls-Royce Merlins on the production line. This engine alone was one of the major contributing factors to winning the war for the Allies. (KEY collection)

At 04.30 on September 1, 1939, Leutnant Dilley rolled his Junkers Ju 87B into a screaming dive to attack the Dirschau bridge, on the frontier between Germany and Poland, the first action of World War Two. On that day various workers in several countries were trying to develop rockets and turbojets, but in that the six years that followed battles were fought with piston engines that worked on the Otto four-stroke cycle.

However, there was plenty of scope for variation in the world of the piston engine. In 1939 fighters in the USA, USSR and Japan had air-cooled radial engines, as did bombers in the UK, USA, Japan and Italy. On the other hand about 60% of fighters in the UK and Italy had liquid-cooled V-type engines, as did 100% of those in Germany. More astonishingly, the feeling in the UK was that all the future fighters would have liquid-cooled V engines, whereas in the USA the prototype XF4U Corsair, with a blunt-nose radial, became the first fighter in the world to exceed 644km/h (400mph).

The chronicler must thus beware of jumping to conclusions. Who would have thought, watching Hurricanes scramble in 1940, that at the end of the war the Hawker production line at Langley would be fitting radial engines? Of course, throughout the conflict particular batches of aircraft were sometimes fitted with different engines, as insurance against a production shortage. Thus, while 11,000 Wellington bombers were fitted with Bristol radial engines, one batch, the Mk.IIs, had liquid-cooled Rolls-Royce Merlins. Conversely, the Merlin powered the mighty Lancaster, except for one batch, again Mk.IIs, that had Bristol Hercules radials.

Concentrating first on the fighters, the position in 1939 was confused, as shown above. Back in 1925 the superiority of the newly-created Pratt & Whitney Wasp, a nine-cylinder air-cooled radial, was so obvious that for a decade it was taken almost for granted that American fighters would have radial engines. Such engines were not only simpler, and usually lighter, than the rival water-cooled Vee type, but they were also cheaper. Because they were shorter, their modulus of inertia was less, making the fighter more agile. Moreover, such engines needed no heavy, high-drag radiator, which if punctured by a bullet meant the engine would overheat and stop.

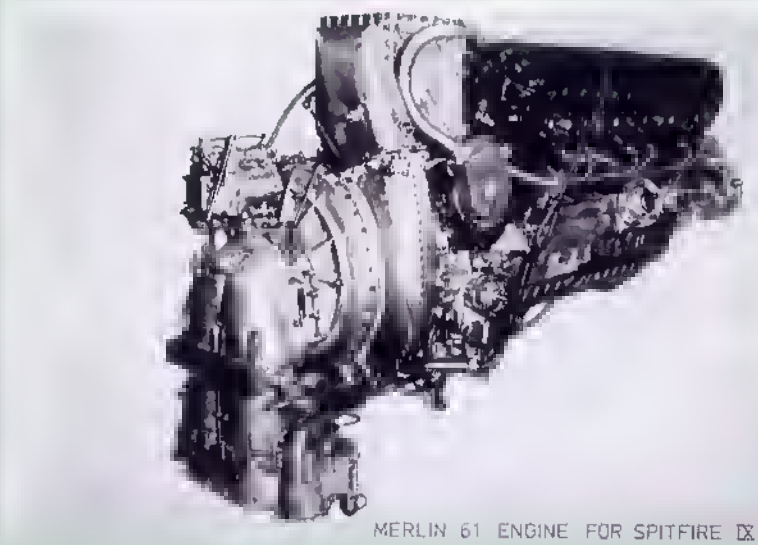
Design choices

Despite these and at least nine other advantages, the air-cooled radial was badly hurt by the victory of seaplanes with V-12 engines in the Schneider Trophy races in 1929 and 1931. These racers did not need draggy radiators, and by the mid-1930s both Britain and Germany had (temporarily) fallen for the belief that a fighter had to have a liquid-cooled engine. This feeling became so strong that in 1935 the US Army's Wright Field sent out a signal that future procurement was going to favour liquid-cooled engines.

In 1938 Hesion Aircraft set out to create the fastest aeroplane in the world, and picked the liquid-cooled sleeve-valve Napier Sabre. Sadly, the cooling proved inadequate, and the aircraft crashed. After a mighty effort, the Sabre was transformed into being acceptable as a fighter engine, resulting in it powering the Hawker Typhoon and Tempest. The Tempest led to the Fury, and though the fastest Fury of all (485mph - 781km/h) was Sabre-engined, the one that went into service had a 2,520hp Bristol Centaurus 18-cylinder sleeve-valve radial.

There was one big area where air cooling reigned supreme and that was in naval aircraft. To avoid the logistic and safety hazard of glycol, almost all naval aircraft used air cooling. To power future carrier-based aircraft, Rolls-Royce produced the Exe, with 24 sleeve-valve cylinders in X formation. It worked like a dream, and powered the company's liaison Fairey Battle for years after the power plant had been stupidly cancelled, consigning British carriers to mainly liquid-cooled fighters and dive bombers.

The main British naval fighter was the Seafire, a hastily-modified Spitfire. This had been designed by Reginald J Mitchell, who had masterminded the Schneider seaplanes. At about the same time, in 1934, Willy Messerschmitt had created the Bf 109. By this time it was obvious - at least to Messerschmitt - that the airframe had to be all-metal stressed-skin, but it was by pure chance that both designers chose to cool the engine by radiators under the inboard rear part of the wing. Hundreds of each type were lost to



MERLIN 61 ENGINE FOR SPITFIRE IX

The later Rolls-Royce Merlins achieved outstanding power at high altitude because of their two-stage supercharger, delivering compressed air through a box-like intercooler. (Author)

The majority of Vickers Wellingtons were powered by Bristol Hercules radial engines. But the Wellington Mk.II was equipped with two Rolls-Royce Merlin X engines. (KEY/Gordon Swanborough collection)

enemy fire, owing to the added vulnerability of the cooling system.

Sydney Camm made the Typhoon less vulnerable by putting the radiator under the Sabre engine. Though this greatly reduced the length of piping needed, this radiator installation also reduced maximum speed by a significant amount.

When in 1940 the British came to North American Aviation (NAA), saying "Can you make us the Curtiss P-40 under licence?", NAA said "We can do better". Having studied the Bf 109 and Spitfire, NAA did indeed do better. Within four months they had designed and flown the Mustang. They used a so-called laminar-flow wing, with maximum thickness much further aft than usual, and put the radiator in a profiled duct beneath the fuselage which in almost all flight regimes gave thrust instead of drag. The result was amazing: Merlin-engined Spitfires could fly at up to 408mph (656km/h) and escort bombers as far as the Belgian coast, while Mustangs, with an almost identical engine, could fly at up to 487mph (784km/h) and escort them to Berlin!

Though an outsider, with no chance of acceptance, Jimmy Martin's Martin-Baker MB.5, powered by a Griffon engine driving contra-rotating propellers, was considered by those familiar with it to be the best fighter of World War Two. Rivals for the title included the Vought F4U Corsair, P-51D or 'H Mustang, Focke Wulf Fw 190 or derived Ta 152, Nakajima Ki-84, Mitsubishi Ki-100, Yak-3, and, at a totally different level of flight performance, the Messerschmitt Me 262A. All had both good features and shortcomings.

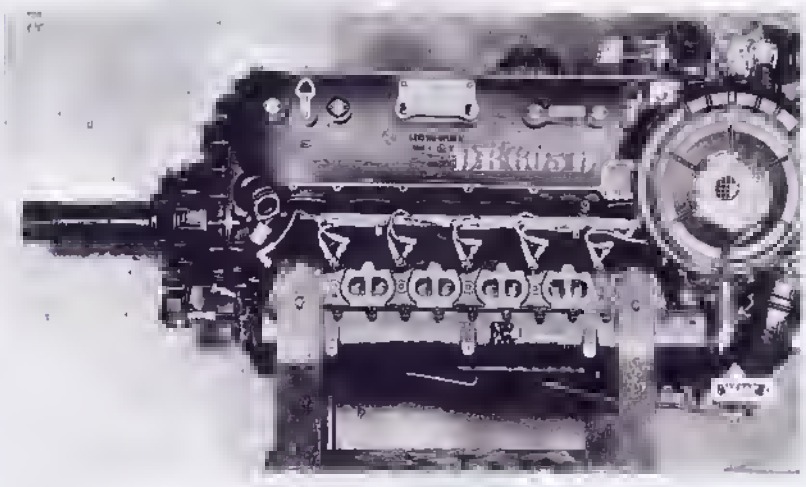
Picking a few points at random, both the Japanese types had radial engines, and the Ki-100 was in essence a Ki-61 with the pointed-nose V-12 engine replaced at short notice by a massive radial! Conversely, while the Fw 190A shocked the RAF by being fitted with a radial engine and flying rings round the Spitfire V, the best versions were widely held to be the Dora-9 and Ta 152 which had liquid-cooled inverted V-12 engines. In a nutshell, the Merlin-Spitfires were medium-sized aircraft with a small engine, the US fighters such as the F4U and P-47, were big aircraft with a big engine, and the German and Soviet fighters were small aircraft with a big engine. The extraordinary thing is, in the author's opinion, all came out fairly even.

In such comparisons one must not overlook the experience and capabilities of the pilot. Hans-Joachim Marseille or Heinz Bar in a tired Bf 109 with a single gun would be a thousand times (literally) more deadly than an average pilot toting eight fifties or four 20mm.

Supercharging

Another absolutely central factor is supercharging. In general, a piston engine can develop power proportional to the crankshaft rotational speed and the amount of correct fuel/air mix drawn into the cylinders on each revolution. Thus, for a given crankshaft speed, a big engine, such as the Daimler-Benz DB 603 (9.8 Imp gals - 44.5 litres), might be expected to develop far more power than a small one, such as the Merlin (a mere 6 Imp gals [27 litres]). Amazingly, through the crucial years 1943-45, these engines competed roughly neck-and-neck, so that (for example) the He 219A found it hard to beat the Mosquito night fighter. There was little wrong with the DB 603 supercharger, but the key factor was S G 'Doc' Hooker's invention in 1941 of the two-stage supercharger and intercooler. This greatly increased the mass of mixture that could be blown into the cylinders at high altitude. This not only transformed the Spitfire and Mustang, but also enabled them to take on fighters powered by engines almost 70% larger and beat them, especially at high altitude.

A few of the fighters, notably the P-38 Lightning and P-47, were equipped with a turbosupercharger, driven by the engine's own exhaust gas. By extracting heat otherwise dumped wastefully overboard, and using it to drive an extra supercharger, the turbo increased engine power, especially at high altitude, and also extended distance flown per unit mass of fuel. However, apart from the extra weight ▶



In contrast to the Merlin, the rival Daimler-Benz DB 605 had inverted cylinders, and a supercharger mounted on the side. (Author)

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The Lockheed P-38 Lightning was powered by a pair of 1,325hp Allison V-1710 engines. Adding to their complexity was the extensive ducting and piping for the intake air, exhaust and engine coolant. (KEY collection)

and cost, the main drawback was the need for long, heavy and vulnerable ducting, taking the white-hot exhaust back to the top of the tail boom in the P-38 and to the underside of the rear fuselage in the P-47. More piping then had to feed the compressed air back to the engine.

A seemingly better idea was simply to gear the exhaust turbos to the crankshaft. This was done eventually, and the Wright R-3350 Turbo-Compound gave turboprops prolonged competition in the 1950s. This engine was fitted with three exhaust turbos spaced 120° apart at the back. Each put 200hp into the crankshaft, and thence to the propeller, which would otherwise have been wasted, but it matured into a world where fighters and bombers were propelled by turbojets.

The Turbo-Compound was basically a conventional two-row radial, but in their desperate quest for power, designers tried many unconventional schemes. Armstrong Siddeley's Deerhound, tested on a Whitley, had three rows each of seven cylinders. The Junkers Jumo 222 had six banks each of four liquid-cooled cylinders, and the 4,000hp BMW 802 was in effect two radial engines back-to-back, each with 14 liquid-cooled cylinders.

As the biggest engine firm of all, Pratt & Whitney experimented the most (it was Churchill who said "The Americans can be relied upon to take the right decision – after they have tried everything else"). Impressed by Bristol designer Roy Fedden's sleeve valve, Pratt's top engineers Mead and Hobbs schemed a family of liquid-cooled sleeve-valve engines which could hardly have been less like the simple air-cooled radials for which the East Hartford firm was famous. Biggest was the H-3730, like a bigger Sabre but with upright cylinders and two enormous aftercoolers between the supercharger and the cylinders.

Army Air Force Chief General 'Hap' Arnold said "Great engine, but why bother? You can get over 3,000hp from well-proven Wasp cylinders". So Pratt switched to the R-4360 Wasp Major, with four rows of seven traditional air-cooled poppet-valve cylinders. In parallel, rivals Wright, Lycoming and Chrysler all produced impressive piston engines in the 2,300-3,000hp class. They powered such impressive aircraft as the Boeing XF8B, Vultee XP-54 and Republic XP-47H and XP-69. These expensive monster fighters were in fact inferior to the P-51D Mustang. In any case, they were not wanted, because of the sudden emergence of the jet engine as a serious competitor.

Jet engines

Rocket technology goes back at least a thousand years, but it was not until the 1930s that serious efforts began to use rocket thrust chambers fed with liquid propellants. Leaders in this tricky and dangerous technology were Glushko and Korolyev in the USSR and Walter in Germany. So far it has had little impact on military aircraft design, and I am sure the Me 163B Komet killed more of its own pilots than it did of the enemy's. I would not have enjoyed being eaten alive by High-Test Peroxide spilt from tanks ruptured in a bumpy landing.

In contrast, the turbojet was exactly what the world had been waiting for. It is almost unbelievable that its invention by Frank Whittle in 1929 should have been ignored. This was partly because young fighter pilots are not supposed to be technical whiz kids, and partly because the expert asked to give an opinion on the idea (A A Griffith) saw Whittle as competition, and submitted a very negative assessment. Thus it was that the Royal Air Force did not have squadrons of jet aircraft in 1936. Instead, when in that year Whittle and three friends scraped together just enough money to make the world's first turbojet, hundreds of engineers in Germany were being marshalled to do the same.

Whittle began testing his radical new engine on April 12, 1937. What followed were months of talk and procrastination, and it was only when USAAF General Arnold heard about the new engine that Whittle's invention really 'took

olf'. By the end of 1941, General Electric was tooling up to mass-produce Whittle engines, and the XP-59A flew on October 2, 1942. In 1943 Gloster flew the prototype Meteor, and de Havilland the prototype Vampire, but they had no impact on the war.

In contrast, German jet aircraft made an impact on the war which could have been extremely serious. Many companies were involved, but by far the most important actual producers of turbojets were Junkers and BMW. Both decided not to copy Whittle, or the rival Heinkel company, and instead go for the axial type of compressor. This had the disadvantages of being complicated, difficult to design correctly, expensive and more prone to damage, but it appeared to enable a turbojet to be slim, with minimum frontal area.

Fortunately for the Allies, choice of an axial compressor greatly increased the time taken to get German jet engines ready for service. Indeed it was not until the summer of 1944 that Me 262A fighters began reaching a special test unit. Actually the world's first regular jet squadron was the RAF's No.616, equipped with the Meteor I in July 1944, but this distorts the true picture. The handful of Meteors had no effect on the war, whereas the 1,433 Me 262As delivered before VE-Day (when hostilities ceased) caused the Allies some difficulties, in both the fighter and bomber roles. The fact that the Jumo 004B's TBO (time between overhauls) was a mere 30 hours was of no consequence whatever.

THE QUEST FOR PERFORMANCE

The most basic aspect of performance, at least in combat aircraft, is speed. In the pre-jet era many unconventional arrangements were tried in order to fly faster. A famous doodle of six possible fighter configurations by C L 'Kelly' Johnson of Lockheed Aircraft resulted in the P-38 Lightning, in which the pilot sat in a short central nacelle. On each side was a 1,325hp Allison V-1710 engine, behind which was a mass of ducting and piping for the intake air, exhaust and engine coolant, leading variously to a turbosupercharger and coolant radiators in the booms carrying the tail.

This resulted in there being three drag-producing bodies, apart from the wing. This is true of most twin-engined aircraft. Another example of a twin-boom fighter was the Savoia-Marchetti SM.91. In parallel, from 1942, the Italian planemaker also produced the SM.92, which did away with the central nacelle by putting the pilot behind the left Daimler-Benz 605A engine. The same layout was adopted by North American Aviation in the P-82 (later redesignated F-82) Twin Mustang. In fact that excellent aircraft had two cockpits in fuselages rather longer than those of ordinary Mustangs. Combined with impressive wing tankage, the result was one of the longest-ranged of all piston-engined fighters.

Thus, the Twin Mustang did better than most of the fighters, which sought to fly faster by fitting two engines instead of one. A pioneer in this quest for doubled power was the Italian Macchi company. In 1930 it worked with Fiat to produce the MC.72 racing seaplane. This was powered by what were, in effect, two V-12 engines joined together to form a single monster engine of 3,100hp. In 1934 this drove the MC.72 at 440.6mph (709km/h) to set a float-seaplane record which still stands. Each engine drove its own propeller, and by making the propellers turn in opposite directions, it almost eliminated drive torque and the usual spiral coiling of the slipstream. Anyone who flew powerful single-propeller aircraft will confirm what a blessing that would be!

Making things easier for the pilot usually came some way down the list of design objectives, but as it could be combined with increased performance I am surprised at how few designers copied the MC.72 propulsion system. One of this tiny group was General Vernisse, Director of France's Arsenal de l'Aeronautique. In 1939 he decided that two centreline engines was a good idea, and the result was the Latecoere 299A, a modified torpedo bomber. The poor pilot was moved back to make room for a second Hispano-Suiza V-12 engine in front of him. Painted in Luftwaffe markings, this test-bed was eventually destroyed by an RAF bomb, but not before it had spurred Vernisse to design the VB.10 described later.

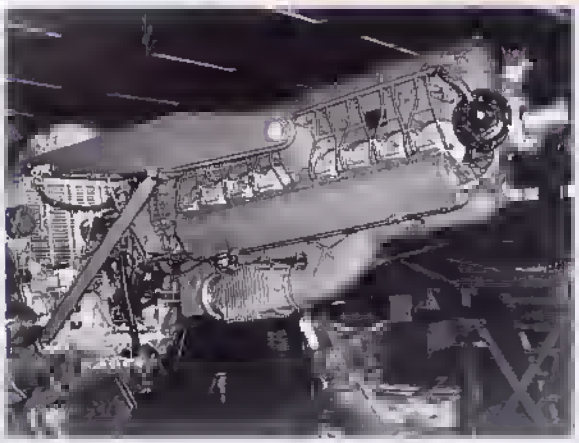
Where fighters are concerned there is much to be said for putting the engine behind ▶

Below: **One of many outstanding engines that took too long to develop; the German Jumo 222 had 24 liquid-cooled cylinders. One application of this 2,500-3,000hp engine was the Ju 288A.** (Author)

Above left: **With demand for the Merlin so high, the Lancaster Mk.II was powered by Bristol Hercules radials. However, the performance of this version was inferior to the Merlin-powered aircraft and only 301 were produced.** (KEY/ Gordon Swanborough collection)

The marriage of the superb North American P-51 airframe with the Rolls-Royce Merlin engine produced the Mustang - one of the best piston-engine fighters of World War Two. (KEY - Duncan Cubitt)

The massive 28-cylinder Pratt & Whitney R-4360 four-row Wasp Major radial was the largest production piston engine produced in the USA. It was used extensively after the war to power such types as the Convair B-36 Peacemaker and the Boeing C-97 Stratocruiser. This sectioned example is on display at the Seattle Museum of Flight. (KEY - Mark Nicholls)



Above: The only pointed-nose Thunderbolt was the P-47N, powered by the Chrysler IV-2220. This 16-cylinder engine was matched with GE's CH-5 turbosupercharger under the rear fuselage. (Author)

Although the Bristol Centaurus-powered Hawker Fury/Sea Fury is more famous, one example was fitted with the Napier Sabre VII engine used in the Typhoon and Tempest and had outstanding performance. (KEY/ Gordon Swanborough collection)

the pilot. It enhances manoeuvrability, helps protect the pilot and leaves the nose free for armament. Bell Aircraft was the first to go into production with mid-engined fighters, both the P-39 Airacobra and P-63 Kingcobra very successfully having their liquid-cooled Allison V-1710 engine behind the pilot and driving the propeller via a long shaft. Fisher Body took the idea further with the XP-75 Eagle, which used the monster Allison V-3420 (two V-1710 engines joined side-by-side) yet was easily outperformed by a P-51 with just one.

Several designers were impressed by the Airacobra. The Italian Piaggio firm even decided to copy the mid-engine idea but using an air-cooled radial - which could hardly fail to be a major challenge. The resulting P.119 began flying on December 19, 1942, powered by an 18-cylinder 1,700hp Piaggio P.XV. Cooling air rammed in under the nose managed to escape round the fuselage amidships.

TRACTORS AND PUSHERS

Of course, if you are really desperate you can have one engine in front of the pilot and another behind. The first such monstrosity to fly was the Japanese Kawasaki Ki-64. First flown in December 1943, this was said to be powered by "a 2,350hp Kawasaki Ha-201". This actually comprised an Ha-40 (a Daimler-Benz DB 601A made under licence) in the nose, and a second amidships, behind the cockpit, driving a contra-rotating propeller via a long shaft. The second example of such a twin-engined fighter was the French Arsenal VB.10, already mentioned. This slowly took shape during the war, and flew on July 7, 1945. Powered by a Hispano-Suiza V-12 in the nose and a second amidships, it defeated its objective by being so big and heavy that its performance was no better than conventional fighters.

In the mid-1930s there were a few designers who, mainly for aerodynamic reasons, said propellers should push rather than pull. In 1935 Consolidated Aircraft moved from Buffalo to sunny California, but a small team led by Larry Bell stayed behind. They decided to create radically new fighters, and their first born was the Airacuda, powered by two of the new Allison liquid-cooled V-12 engines. This was radical in itself, but what really shocked the establishment was that the engines were mounted above the wings, driving pusher propellers behind the trailing edge (in front of each engine was a gunner aiming a 37mm gun).

This enjoyed only limited success, unlike its equally radical successor, the Airacobra. A later and even bigger pusher, the Curtiss XP-71, never got built at all. It would have been powered by two 3,500hp Wasp Major engines, driving eight-blade contraprops, and the assessing officers at Wright Field rightly thought a costly fighter with a span of over 82ft (25m) was not a good idea. Neither did they fully approve of the XP-67, the first creation by the infant McDonnell Aircraft. Its XP-67 long-range escort fighter was to have two pusher propellers driven by Continental O-1430 engines. The O-1430 was to have horizontally-opposed cylinders in order to fit inside slight bulges in the wings, but the eager designers at St Louis were hit twice. First, Wright Field rejected the pusher propellers. Then Continental spoilt everything by redesigning the O-1430 as a conventional inverted-V (according to legend, after Charles Lindbergh had waxed lyrical about the Bf 109). Despite these setbacks, the infant McDonnell team still managed to fly the XP-67, though it looked as if it had been run over by a steam-roller.

While Continental switched from a horizontally-opposed layout to a conventional inverted-V, rival Lycoming stuck with the former scheme. In the late 1930s both these firms, previously known only for small low-performance engines, vied with big rivals Pratt and Wright in creating engines of ever-greater power. I have already mentioned how General Arnold got Pratt to abandon its

The American Bell P-59 was the country's first jet-powered fighter and flew before the British Meteor. (USAF)

impressive sleeve-valve engines. One of these, the X-1800, had been picked by Vultee to power its XP-54. Popularly called the Swoose Goose, this fighter had been designed by Richard Palmer to fly at (he said) 510mph (820km/h). In order to leave the nose free for two 'fifties' and two monster 37mm cannon, he designed the Goose as a pusher, with the radiators inside the wings. One of the most advanced aircraft of the 1940 era, it was not killed off by cancellation of the desired engine. Palmer switched to the even more powerful Lycoming XH-2470, an engine created by putting two O-1230s on top of each other. Thus, it resembled a Napier Sabre with poppet valves. However, the Vultee creation was rather big and complex (the pilot boarded by strapping into a power-hoisted seat) and it missed its design speed by an embarrassing 129mph (207km/h)!

The Swoose Goose was one of more than 30 designs of warplane with the tail carried on twin booms. One of the first was the G.I, designed in the Netherlands by Fokker in the mid-1930s and flown in 1937. This preceded the P-38 in having a central nacelle and a tail carried on two booms, which extended behind Bristol Mercury or Twin Wasp Junior radial engines. Happy with the result, Fokker went on to create the even stranger D.XXIII, in which the pilot sat between two 510hp Walter Sagitta air-cooled inverted-V-12 engines, one pulling and the other pushing! It might have got into production had not the Luftwaffe invaded and destroyed the prototype in a single strafing pass on May 10, 1940.

Another European fighter with a twin-boom layout was Sweden's Saab J21A. First flown on July 30, 1943, this was powered by a pusher Daimler-Benz DB 605B, similar to that used in the Bf 109G. What makes the Swedish fighter unique (I think) is that on March 10, 1947 it re-emerged as the J21R in which the German piston engine was replaced by a British turbojet, the de Havilland Goblin. Speed leapt from 398mph to 497!

When the demands are for extra range or altitude, long-span wings are as important as special propulsion. Britain's Westland Welkin had a span exceeding 70ft (21.3m), but the engines were fairly standard two-stage Merlin 70-series. Almost the only special high-altitude British bombers, the whale-like Wellingtons Mk.V and VI, were again rather half-hearted. The Hercules engines of the former never performed as promised with added turbosuperchargers, while the Merlins of the Mk.VI were again ordinary 60-series.

In contrast, the Germans went to great lengths to achieve performance at high altitude. Indeed, it is possible to go too far in this direction.

Jet-powered aircraft first entered combat with the Luftwaffe, in the shape of its Messerschmitt Me 262s. Although crude by modern standards, the early Jumo 004 turbojets gave the aircraft breathtaking performance. (KEY collection)

The Junkers Ju 86R series had specially supercharged Jumo 207 diesel engines boosted by the injection of nitrous oxide, together with a considerably increased wingspan. The Henschel Hs 130 tried so hard to fly ever-higher that it never got into service. The final Hs 130E version had a Daimler-Benz DB 605 (the engine of most Bf 109s) inside the fuselage driving nothing but an enormous supercharger feeding air to the two DB 603 engines on the wings (which drove the propellers). The result was an aircraft capable of flying long distances at heights exceeding 49,200ft (15km), but it was so troublesome that, like most of the complicated aircraft of history, it never entered service.

In summing up it is clear that aircraft propulsion enjoyed a tremendous rate of development due to the war. Today many of the technological innovations made during the conflict are still in use - notably the jet engine. ■

Gloster Meteor Is of 616 Squadron lined up at dispersal in 1944. The unit was the first operational jet squadron in the RAF and its aircraft were powered by the Rolls-Royce Welland. (KEY collection)

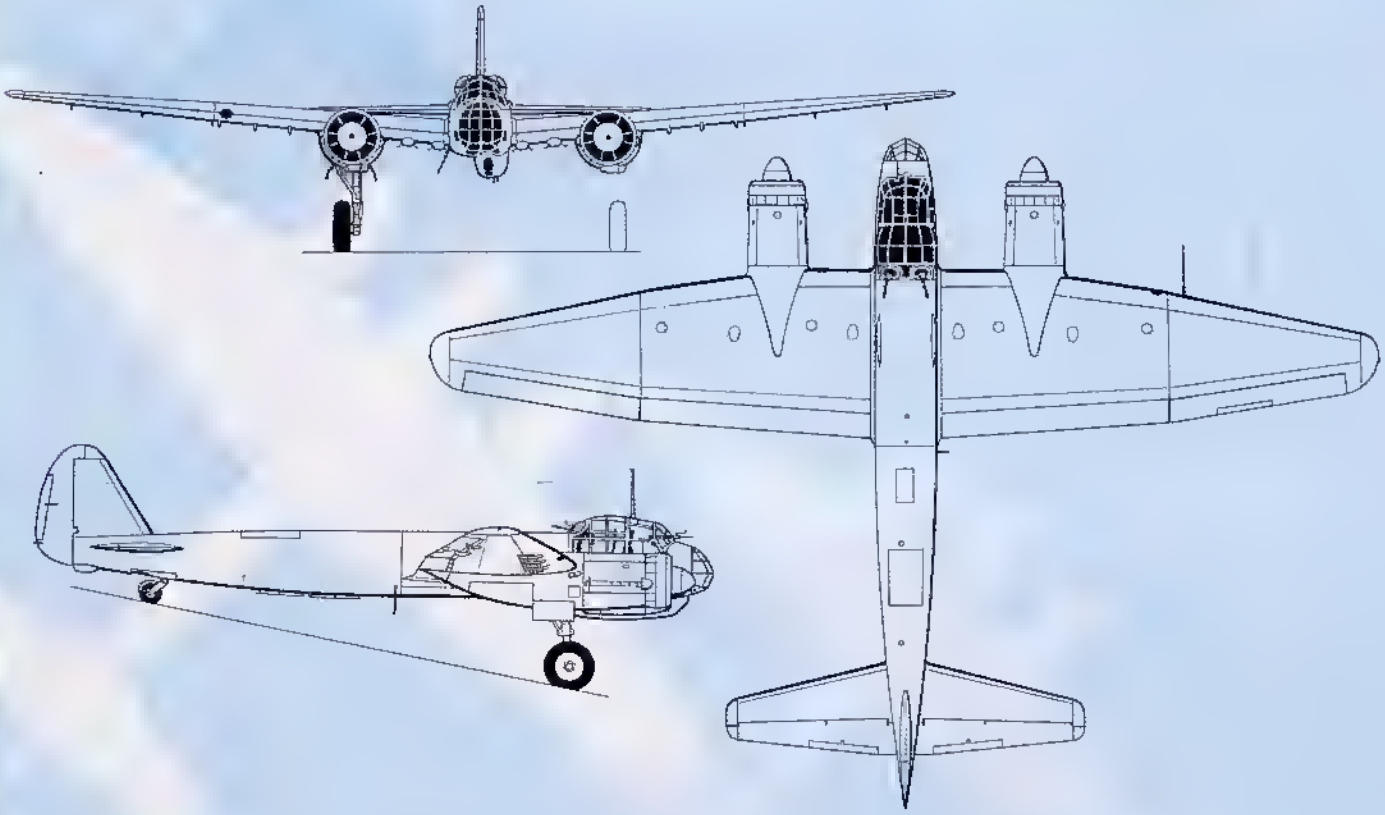
Many regard the twin-engined Junkers Ju 88, Ju 188 and Ju 388 family as the German equivalent of the British Mosquito, although the Junkers design appeared earlier in 1936. Initially conceived as a fast medium bomber, the first Ju 88A models entered service in 1939. From the outset the aircraft could carry an impressive bomb load – up to 6,600lb (3,000kg) which compares well with the load later carried by American four-engined B-17s.

The Ju 88 was eventually built in a bewildering number of variants and serves as a bomber, heavy fighter, night fighter and reconnaissance aircraft. The many sub-variants usually indicated a change of powerplant or different armament combinations. The aircraft served in all theatres with the Luftwaffe and was in front line use throughout the entire war. The bomber versions were easily distinguishable by their glazed nose: fighter and night fighters lacked the glazing, the nose being used to house additional guns and radar installations.

As the type progressed through various variants and sub-variants, more powerful engines were fitted and some models

A night fighter variant, the Ju 88C was often equipped with airborne intercept radar and, as shown here, a range of heavy machine-guns and cannon. (US National Archives)

Ju 88A-4, F1+AT, of 9 Staffel, III./KG 76, operating over the Balkans circa 1943-44.
(David Howley)



A Ju 88 bomber variant flies over Russia during operations on the eastern front in 1942. The Ju 88 was the Luftwaffe's most versatile combat aircraft and fought in all theatres in a wide variety of roles. (Bundesarchiv BA Bild 1011-325-2780-10)

SPECIFICATION

Ju 88A-4

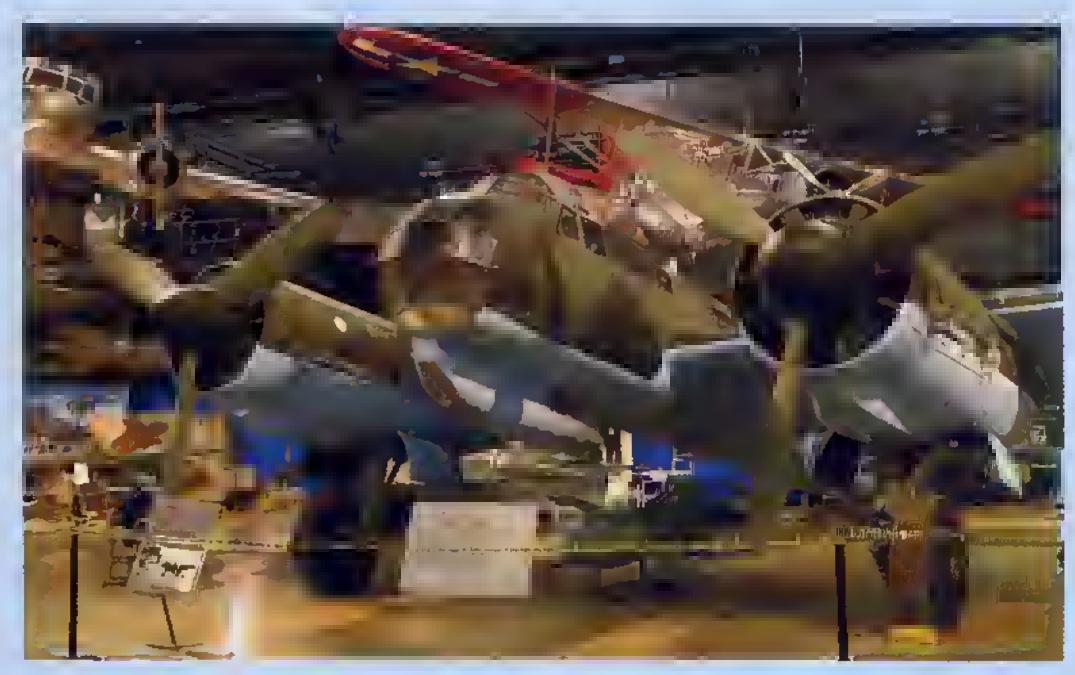
Wingspan	65ft 7½in (20m)
Length	47ft 2¼in (14.4m)
Height	15ft 11in (4.85m)
Gross Weight	30,865lb (14,000kg)
Max Speed	292mph (470km/h)
Service Ceiling	26,900ft (8,200m)
Range	1,696miles (2,730km)
Armament	6 x 0.31in (7.92) machine-guns & 6,600lb (3,000kg) of bombs
Powerplant	2 x Jumo 211J-1

were capable of achieving over 400mph (643km/h), which allowed the aircraft to escape from many Allied fighters of the period. The Ju 88 was also quite agile, hence its use as a fighter and night fighter. By the end of the war, production had reached almost 15,000.

Two other types were developed from the basic Ju 88 design – the Ju 188 and the Ju 388. The Ju 188 was envisaged as a replacement for the Ju 88 and featured an increased wing span and a completely redesigned nose section. Once again, many variants were produced to fulfil the same roles as the Ju 88, although the reconnaissance versions were most numerous, with eventual production exceeding 1,000 aircraft.

The final development of the Ju 88 was the Ju 388, which made its debut in 1944. Only a limited number were built, mostly Ju 388Ls, which were used as a three-man high altitude photo-reconnaissance aircraft. This version had a top speed of 382mph (615km/h), a range of up to 2,160 miles (3,476km) and could fly as high as 44,095ft (13,440m).

This Ju 88D-1 is on display at the National Museum of the United States Air Force, Wright Patterson AFB, Ohio. A former Romanian Air Force aircraft, this type was used mostly for armed reconnaissance. (KEY - Steve Fletcher)



From this... When World War Two broke out the Fairey Swordfish biplane was the Royal Navy's primary torpedo bomber and despite its old technology it continued to fight for a number of years. (Key collection)

...To this In January 1944 the Lockheed P-80 made its first flight. Although it did not see major combat during the conflict, it serves to illustrate just how quickly airframe design, materials and propulsion advanced in such a short space of time. (KEY collection)

THE SIX YEARS OF WORLD WAR TWO SAW A MASSIVE LEAP IN TECHNOLOGICAL DEVELOPMENT AND INDUSTRIAL PROCESSES. TONY BUTTLER AMRAeS LOOKS AT THIS PHENOMENON, THE LEGACY OF WHICH BENEFITED AVIATION INDUSTRY FOR DECADES AFTER THE WAR.

In medieval times, wars were usually a matter of manpower, but by the 20th century things had changed and most of the participants in the two world wars had their campaigns sustained by technology and equipment, plus a massive industrial base to maintain the supply of that equipment. This was particularly true of the air campaign in World War Two. Sir George Edwards, the former Chief Designer at Vickers and Managing Director of the British Aircraft Corporation, once said: "When you get yourself into a war situation one of the basic ingredients is that not only must you have something that is a bit better than the other bloke's, but you have got to have a lot more of them and quick." For the aircraft industry that meant designing new and more advanced aeroplanes and weapons that could be manufactured quickly and using a workforce that employed a relatively high proportion of unskilled labour.

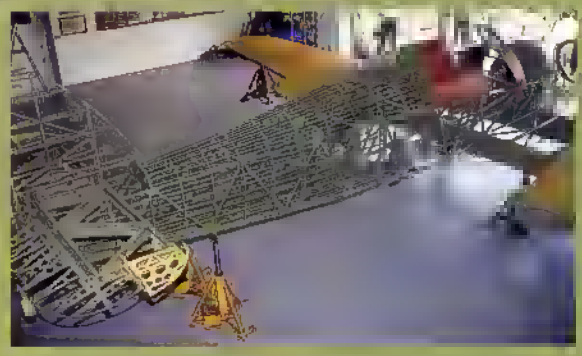
During the 1930s the RAF's bomber force featured types like the Handley Page Heyford, a biplane design with a number of exposed defensive gun installations. (KEY/ Gordon Swanborough collection)

The British Hawker Hurricane was a mixture of old and new technology. It had a steel airframe but, as is evident here, only the wings and front fuselage were covered by metal, most of the remainder was fabric covered. (KEY - Duncan Cubitt)

TECHNOLOGY

When the Second World War started in 1939 the world's aircraft industries had just witnessed the biggest technical upheaval in aircraft design since the Wright brothers at the start of the century. Instead of using a wooden airframe structure covered with canvas and sealed with dope, modern combat aircraft would now be made almost entirely of metal with aluminium frames and skins. In addition, the light but strong alloys that were becoming available allowed designers to produce streamlined shapes to improve their aircraft's performance. Aeroplanes such as the Supermarine Spitfire and Messerschmitt Bf 109 represented the state of the art and brought together these new techniques along with new more powerful engines, better fuels and modern armament. As a result both proved to be superb fighters and both were constantly improved throughout the war. In fact the capability of the world's piston-powered fighters and bombers was to advance in considerable measure during the six long years of war.

However, to begin with some pre-conceived ideas were found to be flawed, in particular turret fighters such as the Boulton Paul Defiant, which were designed primarily to destroy bombers by using a gun turret mounted behind the pilot. This type lacked forward-firing guns and air combat very quickly showed that fighters, besides being fast, had to have all of their guns firing forwards. Turrets, however, were to be an essential ingredient for heavy bombers. From the mid-1930s most air forces were committed to the concept of the defendable multi-engined multi-crew bomber. This would have a battery of defensive machine guns placed at strategic points around the fuselage and in due course some or all of the guns would be housed in multiples in rotating turrets to give a much better all-round coverage.



A vital aspect was bombing accuracy, which required good navigation to get to the target (particularly at night) and good bomb-aiming equipment when over the target. In the first years of the war all of the combatant's air forces were usually restricted to 'blanket' or 'carpet' bombing over a large area in the hope that the important strategic targets within would be wiped out in the general destruction. Before 1942, many Allied night bomber crews never even found their targets but, gradually, new navigation aids were created which made the task much easier. In 1940 however, the German air force had used electronic beams to accurately guide its bombers to British targets and these required new countermeasures to deal with them. In fact World War Two was to become very much the battle of the scientists because as new weapons and electronic aids were designed, so the enemy to begin work on a counter.

WEAPONS DEVELOPMENT

By 1945 new equipment and techniques made it possible for specialist units to hit pin-point targets from great heights and destroy them with relatively little waste of attacking aircraft, bombs or surrounding buildings. Bombs, too, had made

In contrast to the Hurricane, the Supermarine Spitfire was an all-metal fighter, but was more complex to maintain than the Hurricane. (KEY - Tony Dixon)

Boulton Paul's Defiant was armed solely with a turret behind the pilot. This made it particularly ineffective against German fighters but it did have some success as a night fighter. (KEY/Gordon Swanborough collection)

The ultimate conventional free-fall weapon developed during World War Two was the 22,000lb Grand Slam earthquake bomb, dropped by specially-modified RAF Lancaster bombers. This example is on display at the BBMF visitors centre at RAF Coningsby. (KEY - Jarrod Cotter)

great strides. In the early years the RAF's bombs were small; some weighed 2,000lb (907kg) but most were around 500lb (227kg), yet in 1945 the RAF acquired its first 'Grand Slam' bombs, which weighed 22,000lb (9,979kg).

Although designed to free fall, 'Grand Slam' had offset fins to ensure it would spin during its descent and a slim and very aerodynamic shape, factors which were designed to help achieve an accurate delivery. 'Grand Slam's designer, Barnes Wallis, also created a special bouncing bomb that was to be released at very low level and then bounce across the water to hit the sides of dams and split them open. The famous Dams Raid, which made use of this weapon, took place in May 1943. However, no weapon could match the destructive power of the two atomic bombs dropped on Japan in 1945 by the US Army Air Force. These were infinitely more devastating than anything seen before and such weapons were to shape the balance of world power for many decades to come.

In contrast, ground attack aircraft took to carrying relatively small, unguided rocket projectiles for hitting ships, tanks and other small targets, and these were employed extensively during the battles in Europe during the final year of the war. Airborne torpedoes and anti-submarine depth charges were also improved and refined as they became vital elements in the campaigns in both the Atlantic and Pacific Oceans. The unguided rocket was a new type of aircraft store but it was the Germans who actually introduced the first large-scale unguided weapons in the form of the V-1 and V-2 'terror weapons'. The V-1 was essentially the world's first cruise missile while the V-2 was the world's first ballistic missile and both were tremendous technical achievements. However, the volume of explosive they delivered to their targets was small when compared to the effort of getting it there - at this time manned bombers could deliver far more explosive with far greater accuracy.

After six years of war the fighter had moved forward by an enormous margin in both hitting power (typically four 20mm cannon instead of eight 0.303in [7.7mm] machine-guns) and top speed. A key factor raised by the Battle of Britain in 1940 was that machine guns alone did not give sufficient hitting power to easily bring down a metal aircraft. The answer was to replace or combine them with cannon, which in essence were very heavy machine guns that fired explosive bullets of a much larger calibre. Another important aspect was the design of strong undercarriages, particularly important to heavy bombers and to naval aircraft. For example, the Spitfire's relatively light undercarriage was found to be a weakness on the navalised Seafire because it was not strong enough to withstand prolonged landings on moving carrier decks.

Airframe advances

The Spitfire Mk.I of 1939 driven by a Merlin engine could reach a maximum speed of around 345mph (555km/h) and had a service ceiling of 30,500ft (9,296m). The Griffon-powered Mk.XIV, which entered service in January 1944, could attain 448mph (721km/h) and reach 44,500ft (13,564m). The introduction of thinner wings (wing section thickness is defined as the ratio of a wing's maximum thickness to its chord) and ever more streamlined airframes gave less drag and higher speeds. In truth the Spitfire was upgraded and improved by its designers to the point that the Griffon-powered version was really a new aircraft. In contrast the British Hawker company took a different route with its follow-on designs from the Hurricane (the Spitfire's stable mate in the Battle of Britain). Hurricane was succeeded by the Typhoon, then the Tempest and then the Sea Fury, each an all-new design which was clearly related to the previous type but was faster and more agile.

By the end of the war even more advanced aerodynamics were making their appearance. Swept wings matched with new types of powerplant gave the potential for even higher speeds and Germany introduced moderate sweep angles on two of its aircraft – the Messerschmitt Me 163 rocket fighter had about 28° of sweep on the leading edge and the Me 262 jet fighter 18°. Germany had even more radical ideas in the pipeline and the Horten brothers actually built several flying wing aircraft with swept leading edges.

The performance of the heavy bomber was also improved throughout the war. In fact, what constituted a heavy bomber in 1939 looked relatively small in 1945 - this type of aircraft had become much bigger with far greater range and bomb-carrying capacity. In 1940 the British Short Stirling Mk.I had a maximum speed of 260mph (418km/h), a maximum bomb load of 14,000lb (6,350kg) and a range of 2,330 miles (3,749km); the American Boeing B-29 Superfortress which entered service in 1943 had a top speed of 358mph (576km/h) and could carry up to 20,000lb (9,072kg) of bombs for a range of 3,250 miles (5,229km).

Research centres such as Peenemunde in Germany and the British Royal Aircraft Establishment at Farnborough provided back-up to all of these technological improvements. Here new ideas were put to the test and models of new design proposals were tried in the wind tunnel to see if they might work. Once a new aircraft type had been built and flown there were dedicated flight test centres (such as Boscombe Down in Britain, Rechlin in Germany and Zhukovsky in the Soviet Union) to assess them and hopefully clear them for service. It was important to ensure any new aircraft or piece of equipment worked properly and would perform

One of the most ingenious Allied weapons of World War Two was the Upkeep bouncing bomb used by No 617 Squadron during the famous Dambusters raid in May 1943. (KEY collection)

The remarkable de Havilland Mosquito began life as a private venture by the company. As it was made mostly of wood it eased the burden on the metals industry while also providing work for many carpenters and associated workers. In the air its performance was outstanding and it was one of the world's first true multi-role aircraft. (KEY collection)

During the 1930s Britain realised the threat posed by Hitler and began to invest in new aircraft and manufacturing facilities. Once the war was underway production rates rose sharply, a point well illustrated in this view of Avro Lancaster nose sections. (British Aerospace)

well during operations, so it was the job of these test centres to check them thoroughly and locate any weaknesses or flaws. It must be noted that the increasing complexity of new fighter and bomber types meant that the period of time from the initiation of a new design through to its service entry became much longer, particularly so when compared to World War One aircraft.

Aircraft Production

The mass production manufacture of all-metal aircraft required a great deal of new production plant, such as very large and complex machines to bend, shape, drill and machine parts and structures. The introduction of this equipment meant that several skills previously used on aircraft employing a canvas-covered frame, such as woodworking, were fast becoming obsolete and much of the skilled labour force had to be retrained. By 1939 most of the technology for producing aluminium alloys for aircraft (casting, forging, rolling and machining) was in place and pretty well established, and so new alloys produced during the war actually brought only incremental improvements. Wood however, did have one final fling in the form of the British Mosquito multi-role aircraft, which had a light structure made almost entirely of wood and with very few metal parts. De Havilland designed the aircraft to allow a largely redundant force of woodworkers to be fully employed on war work. In the process it produced a fast and highly streamlined design that could be built in large numbers but without adding to the enormous demands that had by now been loaded on to the metals industry.

Having designed the aircraft and introduced the latest elements of advanced aerodynamics, equipment and materials into them, the manufacturers then had to get to work producing their aeroplanes in large numbers. In fact the war brought an insatiable demand for aircraft of all types – fighters, bombers, transports and trainers – and it is interesting to examine how each of the main belligerents handled the problem of producing enough of them.

Britain: During the second half of the 1930s, when it was clear that war with Germany was likely within a few years, the British began a 'Shadow Factory' scheme where the major aircraft manufacturers built many large new factories to supplement their production capacity. As it stood in the mid-1930s the knowledge and experience of production within the British aircraft industry matched its overseas rivals but in certain areas British airframe design had lagged behind. Making up the shortfall required the introduction of new manufacturing techniques (such as sheet metal working), which made the planned expansion an even more complicated process.

The car industry also became very heavily involved, which not only made a lot more factory space available but this efficient organisation was able to bring new techniques for mass production. It operated highly accurate systems of measurement to allow each aircraft off the line to be nearly identical to the last. Accurate dimensional tolerances between duplicate examples of any aircraft part automatically allowed the replacement of damaged parts without difficulty. A large-scale expansion of the motor industry had begun before the aircraft industry had started its changes and by 1939 several motor companies were already specialists in large-scale production. As a consequence, they well understood the manufacture of metal-fabricated bodies and structures.

The mass production of aircraft required a large volume of tools and jigs into which new airframes were mounted and assembled in a logical sequence. It also needed a constant supply of components from all sub-contractors so that a long and constantly moving line of new airframes could be organised with various major sub-assemblies (powerplants, undercarriages and guns) being added in the correct order. An airframe completed at the end of the line would be replaced by a new one added on at the start. Britain's aircraft industry, however, was not totally geared to mass production. Some flexibility was built into the system to allow the introduction of new types and to maintain a balance between quality and quantity. The major sub-assemblies themselves had their own production lines, for example at Rolls-Royce (engines), Dowty (undercarriages) and Rotol (propellers).

The Spitfire Mk.XIV, powered by a Rolls-Royce Griffon engine was over 100mph (160km/h) faster and could fly 14,000ft (4,267m) higher than the original Spitfire Mk.1 (KEY/Gordon Swanborough collection)

One of the most potent RAF piston engine fighters of the war was the Hawker Tempest, powered by the huge Napier Sabre engine. In addition to the mighty engine, the aircraft featured a very thin high-performance wing representing a considerable technical advance over the wing fitted to the company's Hurricane. (KEY collection)

France put up a spirited but in the end fruitless defence against the German blitzkrieg assault in 1940. It lacked a strong enough fighter force to counter the marauding Messerschmitt Bf 109s with aircraft such as this Morane-Saulnier MS.406. (KEY- Duncan Cubitt)

The German V-1 flying bomb was the first of Hitler's terror weapons to be launched against Britain. This rather crude device offered a relatively small destructive punch but nonetheless had a considerable psychological impact. It was also the forerunner of today's highly accurate stand-off cruise missiles. (KEY collection)

From the outset of the war the Germans realised the greater destructive force of the cannon and so it quickly equipped fighters such as the Messerschmitt Bf 109 with a 20mm cannon mounted in the engine vee and firing through the spinner. (KEY collection)

Once war had broken out the threat of bombing against the large factories brought the introduction of 'dispersal' where a huge network of additional sub-contractors, many of them very small, set about making specific parts for the main production lines. Many of the bigger sub-contractors also had 'Shadow Factories'. For example in 1938 High Duty Alloys built a new factory at Redditch specifically to produce aluminium pistons for all of the engine manufacturers, and after six years of war this facility had forged and machined ten million of them. The manufacture of so many aircraft needed a huge workforce and women entered the factories in large numbers to fill the gaps left by having many men on active service; substantial numbers of unskilled labourers were also recruited.

The supply of aircraft to the RAF and Fleet Air Arm was supplemented by orders placed in America. Finally, adding to the deliveries of new airframes, the British created a network of aircraft repair and salvage that not only put back into service machines that had been damaged, but it also 'manufactured' complete aircraft from the undamaged parts of crashed and written-off airframes. This was an important additional source and by the end of 1941 the monthly average of repaired aircraft was 1,312. Keeping a constant supply of spare parts available at air bases was also vitally important.

All of this forward planning paid off because, after the outbreak of war, the aircraft industry was able to sustain its growth of output. By the end of 1938 the rate of manufacture of first-line aircraft had grown to within 42% of the German aircraft industry, which ensured that the RAF had sufficient fighters to fight the Battle of Britain. As war experience was worked back into the industry, the factories reached new heights and ensured that the services were never short of aircraft. During the whole of 1936 1,830 military aircraft were delivered, during the first quarter of 1940 2,381 new aircraft were supplied and in the last quarter of 1941 this figure had risen to 5,338.

France: Here the aircraft industry's input was restricted by the German invasion and eventual control of the country within ten months of the start of the conflict. Prior to this steps had been taken to increase production and to design and build new types but much of the programme was stillborn. In the years immediately prior to the war the French aircraft industry had evolved a series of very promising combat aircraft but the numbers supplied by the time the Battle of France opened in 1940 were nothing like enough to seriously affect the outcome. Some orders were placed far too late and the Armée de l'Air was forced to rely on too many outdated aeroplanes. After the Armistice the construction of some French types was continued to equip new Vichy-controlled units and, during the occupation, French factories also built a selection of German designs.

Germany: Having been left with a very small aircraft industry after the First World War, Germany began to build up its facilities in the early 1930s and, from the start of 1934, it began producing far greater numbers of military aircraft. German planning for war was well organised and the factories were modern, well equipped and easily capable of supplying the Luftwaffe with its needs. In fact for the first three years of the conflict the industry had a lot of spare capacity – in 1939 the output was only 350 fighters and bombers a month and in 1941 this figure had risen to just 580, a sign of overwhelming confidence in success. It was the reversals in the Russian campaign and the war of attrition that came with

The greatest advances in aerodynamics were made by the Germans – the first nation to introduce swept wing fighters, the rocket-powered Me 163 Komet (suspended) and the jet-powered Messerschmitt Me 262. (KEY - Duncan Cubitt)

Above: During the first months of the war Germany had a relatively slow production rate. It was not until it started to suffer significant losses during and after the Battle of Britain, that it intensified its volume production. Here Messerschmitt Me 210s can be seen on the line in one of Germany's many aircraft plants. Later in the war a lot of aircraft production was dispersed to underground facilities. (Bundesarchiv Bild 101I-78-100-35)

Right: The Japanese war machine produciedexcellent aircraft such as this Mitsubishi A6M Zero. However, as the industrial and numerical strength of the USA got the upper hand, Japanese industry suffered from shortages of raw materials and could never hope to compete. (KEY - Duncan Cubitt)

Right: The Soviet Union's aviation industry suffered huge setbacks after the German assault in 1941. But it relocated its entire industrial base further east and was quickly able to produce aircraft on a massive scale. This Lavochkin La-9 first appeared in 1944 but arrived too late to see combat in World War Two. (KEY - Duncan Cubitt)

them that changed the situation - the production rate became far from adequate. In addition the development of improved and more advanced combat aircraft to replace types already in service had been allowed to stagnate when, in contrast, America and Britain had strived to create new and better designs.

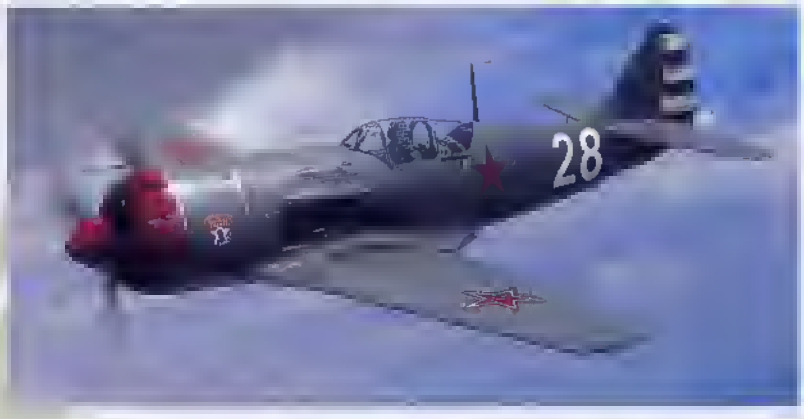
As a result changes were made in 1942 to the organisation of aircraft manufacture and during the first six months fighter production rose by 60%. From 1943 the industry began to take repeated attacks from Allied bombing but the level of output rose enormously, the bombing apparently acting as a stimulant. However, during the autumn and winter of 1944 production rates did begin to fall off. German output was assisted considerably by the extensive use of forced and slave labour and there was rarely a shortage of aircraft, but the Luftwaffe did eventually became short of aircrew, fuel and ammunition. The air raids forced the dispersal of factories eastwards or into new scattered or concealed facilities and an organisation of multiple sources for every part, sub-assembly and even full production lines was introduced. Thus, by the end of the war there was an immense network of aircraft production facilities.

However, the Allied bomber's targets also included Germany's very exposed transport system (on which the dispersed production relied) and the destruction of this, plus the shortage of fuel, meant the delivery of complete aircraft fell away rapidly in the last months of the European war. In fact such were the shortages of fuel and ammunition that new engines could only be tested for just a few minutes and guns went into action without ever having been fired.

Italy: The Italians produced a good supply of military aircraft of all types, some of which bore comparison with the very best aircraft to which they were opposed. In particular some outstanding fighters were flown but, overall, the industry failed to organise an effective system of mass production. As a result the Regia Aeronautica never had enough aircraft to replace those lost in service.

Japan: Before 1941 the supply of modern aircraft to the Japanese armed forces was largely unknown or ignored by the British and Americans, with the result that modern types, such as the Mitsubishi Zero fighter, presented something of a surprise. In fact the Japanese aircraft industry had been expanded with that country's usual speed and efficiency and in the 1930s officials decided the industry should become self-sufficient. Only homegrown designs were to be built although examples of foreign types were bought for assessment and to learn new techniques. When, in 1937, when war broke out with China, the progress of the aircraft industry were kept secret. Output increased sharply and when the attack on Pearl Harbor went ahead in December 1941 the Army and Navy's airborne forces were well supplied with excellent aircraft and pilots.

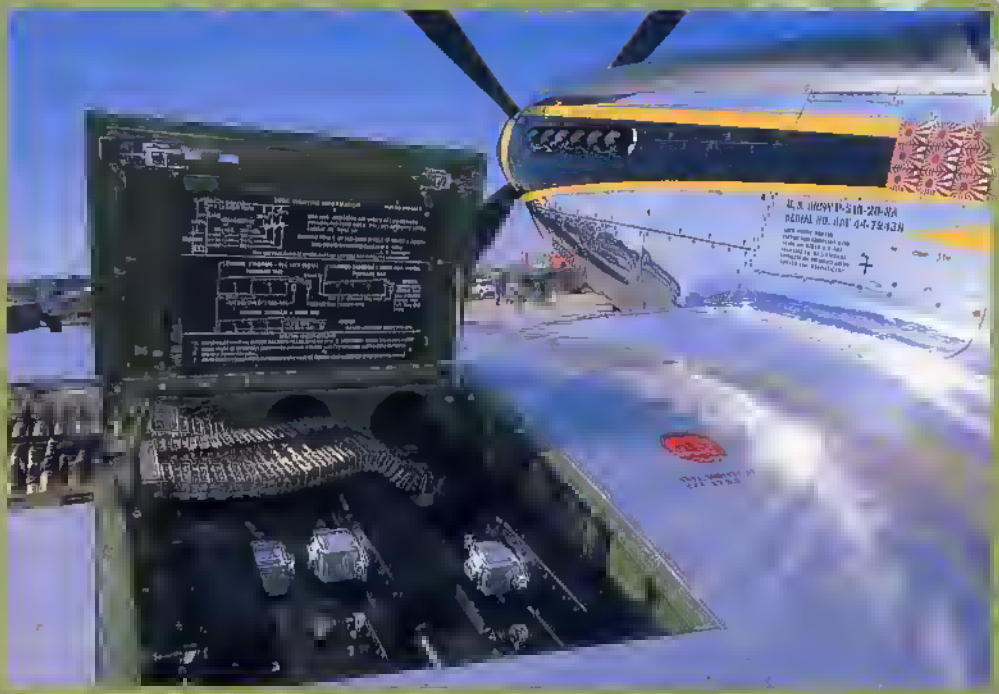
However, the long campaign in the Pacific took its toll. Japan eventually became short of experienced pilots because a great many were lost during several key battles in 1943 and 1944. The industry also became starved of certain raw materials and, throughout the conflict, there was never an organised system of allocating labour; in fact workforces were hit hard by the continual recruitment of civilian workers to the armed forces. Nevertheless, the numbers of new aircraft delivered continued to rise - in 1937 the



total was 1,511 and in 1944 it reached 28,180, but this was not enough to match the Americans. From autumn 1944 onwards the growing effects of American bombing raids contributed to the inevitable defeat, although by the time the end came almost every town and large village in Japan had become involved in some way with aircraft manufacture.

Soviet Union: Like other nations the Soviet Union began a substantial build-up of its aircraft manufacturing capacity during the mid-1930s but the strength of the industry, and the air force itself, suffered badly from the bloody purges of Stalin's leadership of 1937 and 1938. Many leaders of industry and the military were removed from office, some were imprisoned and some executed, and the horror embraced designers and engineers as well. Thousands of aircraft workers were dismissed and numerous research and production facilities were closed. However, when the USSR became aware of Germany's increased production of new aircraft and their quality, attention swiftly focused on to the rapid acquisition of new types.

By Western standards Soviet aircraft were crude but they were designed to the nation's needs. They were cheap and easy to build in large numbers and easy to operate in the field, particularly in the awful conditions of a Russian winter. Up to 1941 production rates increased very quickly and 15,735 examples of all types were built that year. However, the German invasion in 1941 brought with it heavy losses of Soviet aircraft and so, to keep up the numbers, production was limited to selected types only. By early 1942 many Soviet factories had been forced to relocate eastwards to avoid the oncoming German army. New and improved aircraft were now designed and a total of 40,214 were built in 1944 (over 17,000 aircraft were also supplied by America and Britain). Metals shortages forced the use of wood, plywood and composites, which meant that, at the end of the war, the USSR's industry lagged a little behind the West. However, a strong industrial base had been created which ensured that the Soviet Union would soon become a superpower.



Aircraft armament relied primarily on the machine-gun throughout the war. However, technical development was rapid in this field, not least to reduce the physical size of the weapons to fit in the increasingly thinner wings of high-performance fighters, such as the P-51 illustrated here. (KEY - Duncan Cubitt)

United States: The imminence of war also speeded up the design and production of new military aircraft types in America. In the late 1930s a new generation of designs was produced which compared very well against contemporary European aircraft. In addition the need for foreign air arms to re-equip for war brought heavy export orders to America, including supplying Britain and some of her allies aircraft in quantity under the 'Lend-Lease' programme, and this helped to finance the expansion of the country's manufacturing facilities. The German successes in Europe in 1940 forced President Roosevelt to make a call for 50,000 new service aircraft, a seemingly absurd target but one that galvanised the American aircraft industry into massive increases in production capacity. Soon it was able to build aircraft in such numbers and of such quality that America's armed forces could now match the strength of the Japanese.

In fact the USA possessed colossal industrial might which, to date, had been heavily underused – the nation was rather like a sleeping giant waking up. Between 1941 and 1945 the US built more aircraft than Germany and Japan together, and by the end of the war the Army Air Force had 72,726 aircraft (41,961 of which were combat types) and the Navy had 41,180 (28,032 for combat). This really was mass production on a gigantic scale and the result was quite literally history's largest air force. Throughout the conflict the Americans continued to supply aircraft to their allies while also having to build sufficient aeroplanes to support campaigns both in the European and Pacific theatres. Huge air armadas were assembled for the major battles of the war and massive supplies of aircrew, fuel and weapons always supported these. The industrial lead, which America gained, from its war effort has been retained to this day. ■

Left: Such was the pace of development in the USA that as early as September 1942 Boeing flew the prototype of the B-29 Superfortress. This aircraft only saw service in the Pacific theatre, but its effectiveness was immense. (US National Archives)

A factory full of Republic P-47 Thunderbolts. The immense capacity of American industry was a deciding factor in the war and by the end of the conflict the US armed forces had in excess of 100,000 aircraft at their disposal. (US National Archives)

THE RISE AND FALL OF THE LUFTWAFFE

JOHN WEAL EXPLAINS THE METEORIC RISE OF THE LUFTWAFFE AND, AFTER SOME GREAT SUCCESSES, ITS SUBSEQUENT DEMISE.

"Excellent!" exclaimed Hermann Göring, "I had no idea you had progressed so far. All the better!" Adolf Hitler had come to power just two months earlier in January 1933. Now his newly-appointed Reich Commissar for Aviation was making his first visit to the Luftwaffe's secret Rechlin test centre.

Göring's surprise was genuine. For, contrary to long-held belief, it was not the Nazi Party that laid the foundations for the force that was to become the wartime Luftwaffe. The first moves had been made by the Weimar government back in the early 1920s before the ink on the Versailles Treaty had scarcely had time to dry. What the new régime did do was to transform a hitherto covert organization into an air arm of such seeming menace that it quickly became the 'big stick' wielded by the Führer to back up his every new demand on neighbouring territories.

Building the force

No opportunity was missed to convince the air-conscious public of the day – this was, after all, still the era of General Douhet and his famous maxim: "the bomber will always get through" – that the Luftwaffe had become the most modern and powerful air force in Europe. 'Massed' fly-pasts were staged (using almost everything that could be got into the air) and foreign dignitaries and air correspondents were taken on carefully orchestrated tours of airfields and aircraft factories.

The bluff worked. When Hitler re-occupied the demilitarised zone of the Rhineland in March 1936 – his first flagrant breach of the terms of the Versailles Treaty – the western allies did nothing. Emboldened by this success he went on to annex Austria into the Greater German Reich and claim the Sudetenland from the Czechs. He occupied the rest of Czechoslovakia in March 1939, and still the British and French clung to their policy of appeasement at any price.

The Luftwaffe had been instrumental in ensuring the success of all the above ventures simply by its very presence. But by this time the men and machines of the Third Reich's new air arm had also undergone their first real baptism of fire. The Spanish civil war, which began in the summer of 1936, has been rightly described as a dress rehearsal for the wider conflict to come. It certainly revealed the hitherto largely 'civilian' fleet of airliners and mailplanes in their true colours as military transports and bombers.

But the war in Spain threw up some unpleasant surprises as well. One of the biggest shocks was the discovery that the Heinkel He 51 biplane, at that time the Luftwaffe's standard fighter, was completely outclassed by most of its Republican opponents. There are even stories of the Heinkels tucking in close to the bombers they were meant to be escorting for their own protection! The situation was remedied in 1937 with the arrival in Spain of the first models of Willy Messerschmitt's new Bf 109 monoplane fighter.

The most successful fighter pilot of the Legion Condor, to give the Luftwaffe expeditionary force in Spain its correct title, was a certain Werner Mölders. All 14 of his confirmed victories were scored while flying the Bf 109. Mölders was also responsible for introducing the new tactical fighter formation called the Schwarm. This consisted of four machines made up of two mutually-supporting pairs. The same formation was subsequently, if somewhat tardily, adopted by the RAF as the 'finger-four', and then became standard in most of the world's major air forces.

The last of the Legion Condor returned to Germany in the summer of 1939. Within weeks the lessons learned in Spain would be used to devastating effect against Poland. Hitler's attack on his eastern neighbour, launched on September 1, 1939, was one step too far. Britain and France responded by declaring war on Nazi Germany two days later. There was, however, little concrete help the western allies could offer the embattled Poles who soon succumbed to the first Blitzkrieg campaign in military history.

Lull before the storm

In the West the ensuing autumn and winter months were to become known as the 'Sitzkrieg' or 'Phoney war'. There was limited reconnaissance activity along the Franco-German border. To the north, RAF Bomber Command attempted to take the war to the enemy by mounting a series of raids on German naval units and installations on the North Sea coast. The defending Luftwaffe fighters gave short shrift to the unescorted bombers.

Of the 34 Wellingtons sent out on the two raids of December 14 and 18, for example, exactly half were shot down. The result was that for the remainder of the war Bomber Command would restrict its activities over Germany almost entirely to the hours of darkness. It is difficult to say who were the less prepared for this unforeseen turn of events: the RAF's bomber crews or the Luftwaffe's night-fighter arm which, at this early stage of the hostilities, numbered hardly more than a dozen machines.

On April 9, 1940, Hitler, anxious to safeguard his supplies of Swedish iron-ore, invaded Norway through whose coastal waters the precious ore was shipped southwards. The Allies, who were just as intent on halting this traffic as Hitler was in securing it, already had a force at sea en route to Norway. The Germans won the race by a matter of hours. Staging through Denmark, Luftwaffe aircraft quickly climbed the ladder of airfields extending northwards along the Norwegian coastline. From these secure bases they were ideally situated to overcome the small Norwegian Air Force and the few British units sent to their assistance. But long before the campaign in Scandinavia had reached its inevitable conclusion, Hitler had unleashed his invasion of France and the Low Countries.

Having utilized the intervening winter months to add more units to its still far from complete order of battle, the Luftwaffe was to play a crucial role in the Blitzkrieg in the West. By its end, the British Army had been forced back on Dunkirk and into evacuation by sea, and metropolitan France was divided in two: the northern part under German occupation and the southern end controlled by the pro-Axis Vichy government.

Thus far the Luftwaffe had met all the demands made upon it. It had achieved and maintained aerial superiority on every battle front as the ground forces scythed firstly through Poland, and then Scandinavia, the Low Countries and France. Now the only enemy remaining was Britain. But the narrow strip of water separating France from southern England was to prove an insurmountable barrier. Hitler was very

A Heinkel He 111 pilot signs for his aircraft prior to another daylight bombing mission. The He 111 remained at the forefront of Luftwaffe bombing operations throughout the war. (Bundesarchiv BA 146-2005-0067)

Luftwatle personnel take a breather around their Bf 109Es at a base in northern France during the Battle of Britain. (Bundesarchiv BA Bild 1011-058-1784A-14)

Spot the Dorniers! Three Do 17 bombers somewhere over southern England during the Battle of Britain. Third in the triumvirate of Luftwaite bombers, most Dornier units had been re-equipped with Ju 88s before the Battle was over.

much a land commander, and the Luftwaffe had been deliberately structured as a tactical force to support his armies in the field. The forthcoming Battle of Britain was to reveal its inherent weaknesses and shatter the myth of invincibility that had been so carefully fostered since its inception.

The Germans seemed in no hurry to commence the battle. After the fall of France many Luftwatfe units were rotated back to the homeland for much-needed rest and re-equipment. Gradually Göring began to gather his forces along France's northern coast. The first phase of the battle was intended to gain control of the Channel. And in this the Luftwatle was initially successful; severely disrupting Britain's coastal convoys and forcing the RN destroyer flotilla based at Dover to retire out of harm's way.

Battle of Britain

It was when the Luffwaffe bombers began to venture inland that things started to go wrong. The success of the two Blitzkrieg campaigns to date had depended very much on the element of surprise. Now, for the first time, Göring's units were faced with an enemy who was expecting them. Although seriously depleted by its previous commitments in France, RAF Fighter Command

Above right: A Bf 109E of III./JG 2 'Richthofen' takes a welcome break from the Battle in its wooded dispersal area at Octeville, August 1940. (All photos author unless stated)

Heinkel He 111H-2s of 7./KG 1 head across the English Channel in August 1940. Once RAF fighters penetrated the protecting German fighter screen, these bombers were relatively easy prey. (Bundesarchiv BA Bild 1011-385-0593-05)

was ready and waiting. And it possessed one inestimable advantage: the benefit of ground radar (see pages 66-71) to keep its pilots informed of the enemy's position and course.

The Luftwaffe launched the battle in true Blitzkrieg fashion by trying to knock out their opponent's airfields. But Blitzkrieg is, by its very nature, a co-ordinated assault by both air and land forces. It does not work on a strategic level with the use of air power alone. The short-legged Messerschmitt Bf 109s were unable to escort the bombers much beyond the line of the Thames. And when the twin-engine Bf 110s took over escort duties they fell easy prey to the RAF's Hurricanes and Spitfires. The flaws in the Zerstörer, or heavy fighter, concept – one of Göring's pet projects – were cruelly exposed as the Bf 110s began to suffer ever-increasing losses.

Above: The twin-engined Bf 110 Zerstörer was to prove a big disappointment as an escort fighter in the Battle. This machine of ZG 26 disports among the clouds over France unaware of events to come on the other side of the Channel.

Head of the Luftwaffe, Reichsmarshal Hermann Göring chats amiably with his troops in France during the Battle of Britain. However, he became increasingly frustrated at their inability to overcome the RAF. (Bundesarchiv BA Bild 1011-343-0667-35)

Above: Ju 87s Stukas of III./StG 77 kick up dust as they return from a raid, their bomb racks empty. It was this unit's loss of 17 aircraft, plus a further seven damaged, on August 17, 1940, that effectively ended the Stuka's daylight career in NW Europe.

The Junkers Ju 87 Stuka, the very epitome of Blitzkrieg, was also found wanting in the skies of southern England. This cranked-wing machine, which had sown panic and destruction in every campaign to date, was unable to survive in hostile airspace against determined fighter opposition. Its fearsome reputation in latters. The Stuka disappeared forever from the daylight skies of NW Europe.

As a result of their heavy losses, and without realizing just how close they had come to attaining their objective, the Luftwaffe's bombers abandoned their attacks on Fighter Command's airfields and turned their attention instead on London. It was the respite the RAF so desperately needed. Thereafter they slowly began to win the war of attrition until finally, like their Bomber Command counterparts before them, the Heinkels and Junkers of the Luftwaffe were forced to resort to operating by night.

Dornier Do 17Z-1s head for England at the height of the Battle of Britain. (Bundesarchiv BA Bild 1011-341-0456-04)

A Bf 109 after force landing on a beach in northern France, having just made it back across the Channel. (Bundesarchiv BA Bild 1011-344-0741-29)

KG 100 was tha Luftwalfe's premier night pathfindar unit. This He 111 barely mada it back to the coast of France whara it was writtan off in a spectacular crash landing.

The British now recognise the Battle's coming to a successful close on October 31, 1940. The Luftwaffe at the time made no such distinction. To them the night blitz on Britain's cities during the winter of 1940-41 was an ongoing part of their aerial offensive in the west. But this nocturnal onslaught was not to be the forerunner to an invasion of southern England in the spring of 1941. By then Hitler's mind would be focussed on a different enemy.

Change of Emphasis

By early 1941 the Luftwaffe was beginning to change form. No longer exclusively a concentrated, Blitzkrieg-orientated attack force, it was now having to shoulder additional defensive responsibilities too; not only along the length of the newly-occupied NW European coastline from Norway to the Bay of Biscay, but also within the borders of the Reich itself where the RAF was stepping up its night bombing offensive. One response to the latter development was the remustering of several redundant Bf 110 Zerstörer units for the night-fighter role.

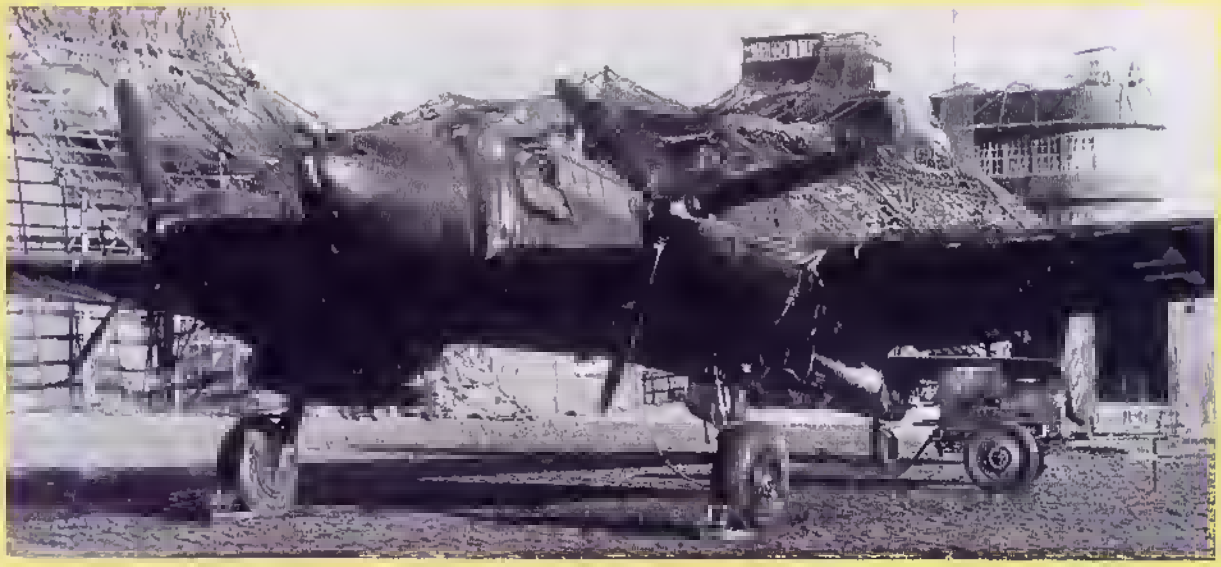
The Ju 87 was also about to get a new lease of life. Italy had entered the war towards the end of the French campaign back in June 1940. Now, seven months later, the Italian Army was in deep trouble, both in Greece and North Africa. In answer to his Axis partner's pleas for help, Hitler ordered the transfer of a complete air corps from Norway down to Sicily. Its tasks were threefold: to neutralise the island of Malta by bombing, to disrupt British supply convoys in the Mediterranean, and to support the Axis ground forces in North Africa.

Faced with less intensive local opposition, the Stuka came back into its own. After operating over Malta and the convoy routes, it was employed primarily in support of the Afrika Korps. The Luftwaffe would retain a small but potent force of fighters and attack aircraft in Africa until the Korps' final surrender in Tunisia in May 1943.

Meanwhile the Italian troops invading Greece were in danger of being pushed back across the Albanian border whence they had come. Wanting to stabilize the Balkan situation, Hitler had already dispatched a number of Luftwaffe units to Romania as a safeguard. But when Britain sent troops from Egypt to Greece's aid, and her neighbour Yugoslavia refused to join the pro-Axis alliance, the Führer decided to act by mounting a joint offensive against the two countries.

Tha Messarschmitt Me 210 was not a particularly successful dasign, although it did see plenty of sarvica. This axample is seen at low-laval ovar Tunisia in 1942. (Bundesarchiv BA Bild 1011-421-2051-18)

I./KG 51 crew mambars gat ready to board thair Ju 88A-1 in northarn France during tha Battle of Britain. The Ju 88 was arguably tha most versatile of all Garman aircraft during World War Two. (Bundesarchiv BA Bild 1011-402-0265-03A)



Left: The Bf 110 enjoyed a new and successful lease of life as a night-fighter. An early all-black machine of III./NJG 1 outside a camouflaged hangar (possibly Deelen, Holland).

Below: A fearsome-looking Fw 190A-1 of the conversion detachment based at Abbéville in France, spring 1942.

What followed was pure Blitzkrieg: a fast-moving, co-ordinated air and ground campaign designed to overwhelm the enemy in the shortest time possible. Yugoslavia capitulated in less than a fortnight. Mainland Greece followed suit not long after. But Luftwaffe operations in the area did not cease until a costly airborne landing captured the island of Crete on June 1st.

The Balkans campaign was to prove even more expensive in another way. Hitler had never been wholeheartedly behind the plans to invade southern England. His mind was focussed instead on National-Socialist Germany's traditional foe; the communist Soviet Union. As early as December 18, 1940 – with the night blitz on Britain yet to reach its peak – the Führer's War Directive No.21 stated: "The German Armed Forces must be prepared, even before the conclusion of the war against England, to crush Soviet Russia in a rapid campaign (Operation Barbarossa)".

The Directive went on to order that all preparations "will be concluded by 15 May 1941". But on that date many Luftwaffe units earmarked for Barbarossa were still engaged in the Balkans. Hitler was forced to postpone the offensive for four weeks; four valuable weeks of summer weather which could have seen German ground forces well on their way to Moscow.

The Russian Front

Finally launched on June 22, 1941, Barbarossa was the last, and by far the biggest, Blitzkrieg campaign of the war. It began in tried-and-tested fashion with attacks on the enemy's airfields and forward landing grounds. The results were spectacular. By the close of the first day's fighting 322 Red Air Force machines had been shot down – and some 1,500 destroyed on the ground! At first Hermann Göring refused to believe the latter figure. But when the 31 fields that had been the targets of the Luftwaffe's opening strikes were captured, examination of the wreckage proved that the original estimate had, if anything, been on the low side.

With the Soviets reeling from the onslaught, the three main German Army groups, each supported by its attendant air fleet, began to drive deep into Russian territory. It was Army Group Centre, aiming at the Russian capital, which achieved the greatest initial successes. In a series of huge pincer movements whole Soviet armies were surrounded and hundreds and thousands of prisoners taken.

Keeping pace with the ground advance, the Luftwaffe enjoyed almost total air

Above left: Winter-camouflaged Ju 87D Stuka of StG 2 'Immelmann' over Russia. Note the extended fuse rods on the underwing bombs.

Left: The massive Messerschmitt Me 323 Gigant saw use in the Mediterranean and in Russia. It could carry light armour as well as supplies and troops but was slow and lacked manoeuvrability, thus making it easy prey for allied fighters or even light bombers. (Bundesarchiv BA Bild 1011-596-0367-05A)

Pilots discuss how to attack a B-24 Liberator, working out their tactics with wooden models at a training centre in Germany. (Bundesarchiv BA Bild 1011-565-1406-30)

supremacy above the front lines. But it was the vastness of the country behind those lines that militated against the Luftwaffe which still was - and would remain until the end - essentially a tactical air force. Moscow suffered its first night bombing raid exactly one month into the campaign. But this was a minor affair. It was the Eastern Front, like no other theatre of war, that would show up the Luftwaffe's failure to develop an effective, strategic four-engined bomber - especially after the Soviets evacuated much of their manufacturing plant beyond the Ural mountains, well out of range of the twin-engined Heinkels and Junkers.

On November 15, 1941, the spearhead of Army Group Centre ground to a halt in the snow and ice less than 20 miles from the walls of the Kremlin. They would get no further and be forced to retire two months later. The four-week delay at the start of the campaign had indeed cost Hitler dear. And when the offensive was resumed in the spring of 1942 the Soviet capital was no longer the objective. The main thrust was now to be made by Army Group South; its twin aims the capture of the Caucasian oilfields and the city of Stalingrad.

This southern sector of the front, the Ukraine and the Caucasus was the arena in which the most successful fighter pilots in aviation history - men like Hartmann, Barkhorn and Rall - achieved the greater part of their incredible scores. But no amount of personal successes in the air could affect the progress of the war on the ground. The Caucasian oilfields remained tantalizingly out of reach, and in the winter of 1942-43 the ruins of Stalingrad witnessed the death of Germany's 6th Army and with it the turning point of the war in the East.

Defending the Reich

Meanwhile the Luftwaffe's war in the West had been primarily a defensive one. With the bulk of its strength engaged in Russia, only a skeleton fighter force remained to guard the North Sea and Channel coasts.. In 1941 RAF Fighter Command, which had itself been very much on the defensive over southern England only the year before, began to 'lean' into France. And America's entry into the war in December of that year presaged the appearance of a potentially even more powerful opponent for the Luftwaffe units based in NW Europe and the Reich.

Having cut its teeth during the latter half of 1942 on the Bf 109s and Focke-Wulf Fw 190s protecting targets in France and the Low Countries, the US Eighth Air Force dropped its first bombs on Germany on January 27, 1943. This marked the start of a two-year campaign which, in conjunction with the RAF's ever-growing night offensive, would lay waste to much of Germany's heartland.

At first the Luftwaffe pilots defending the

Above: A ZG 26 Bf 110 in Greece during 1941. It was at this time that the Luftwaffe's problems were really starting to hit home, as it struggled to operate on three fronts. (Bundesarchiv BA Bild 1011-432-0771-21A)

An Italian SIAI SM.79 of 278° Stormo 132° Gruppo very low over Tunisia in 1941. (Bundesarchiv BA Bild 1011-415-1611-02A)

Reich more than held their own. Waiting until the escorting fighters reached the then limit of their range and were forced to turn back, the Focke-Wulfs and Messerschmitts would attack the unprotected bomber boxes as they pressed on alone deeper into Germany. The US heavy bombers suffered some grievous losses, particularly during two raids in August and October 1943, each of which cost the Eighth Air Force 60 Flying Fortresses.

The Americans steadily increased their numbers. It was, however, the advent of the long-range P-51 Mustang in the winter of 1943-44 that tipped the scales finally and irrevocably in their favour. The Luftwaffe tried to respond in kind by building up its own strength. But there were only so many fighter units that could be stripped from the other, already thinly-stretched fighting fronts to bolster the Defence of the Reich organisation. Unable to compete in numbers, the defenders tried various innovative weapons and tactics to even the balance, including air-launched rockets and the dropping of bombs on to the tightly-packed enemy bomber formations from above. The twin-engine Bf 110 Zerstörer, now armed with large ventral cannon, even re-appeared briefly in the daylight skies of the Reich. All to no avail.

If, by day, the 'Mighty 8th' was battering the Luftwaffe into submission by sheer weight of numbers alone, it was a different story during the hours of darkness. RAF Bomber Command was also numerically stronger than the Luftwaffe night-fighter arm opposing it. But the battle for the Reich at night was made up of individual, one-on-one encounters of fighter versus bomber. The five-year nocturnal campaign was also much more of a see-saw affair, dictated not simply by an inexorable build-up of numbers, but by a succession of technological and electronic advances, measures and counter-measures – new navigational aids for the RAF bombers, improved airborne radar equipment in the Luftwaffe's fighters.

The one major 'secret' weapon introduced during the campaign, which reportedly remained unknown for many months to RAF intelligence officers – and, more crucially, to the bomber crews themselves – was the twin upward-firing cannon fitted to many of the Bf 110 and Ju 88 night-fighters. Luftwaffe pilots would approach from below, the bomber's blind spot, and fire obliquely upwards into the enemy's engines or wing tanks. Many RAF crews perished in this manner, literally not knowing what had hit them.

Back on the offensive

resumption of bombing raids on London. Again by denuding other fronts, mainly the Italian, a force of close on 500 bombers was assembled in NW Europe. Comprising mainly late-model Ju 88s and 188s, it also included nearly 60 Heinkel He 177s. This ill-starred machine – the only four-engine bomber to enter operational service with the Luftwaffe (if one discounts the Fw 200 maritime patrol bomber developed from an earlier airliner) – was plagued throughout its short and undistinguished career by problems arising from its paired engines.

The first raid of Operation Steinbock, or the 'Little Blitz' as it became known in England, was flown on the night of January 21-22, 1944. Unfortunately for the Luftwaffe bomber crews, however, the British had learned of the impending operation through Ultra intelligence intercepts and the UK's night-fighter and anti-aircraft defences – like Fighter Command's pilots four years earlier – were ready and waiting.

Over the next four months the Luftwaffe was rarely able to mount more than 100 sorties in any one night. Operational losses and serviceability difficulties soon reduced the force to less than half of its original strength. The last major raid on London took place on the night of April 18-19. As a retaliatory gesture Operation Steinbock was not in the same league as the 1,000+ bomber streams that would be parading high above Germany in the months to come. But even as Steinbock was winding down with a few final desultory attacks on coastal targets, the Eighth Air Force was curiously absent from the skies of the Reich.

Invasion

The reason for this was that the American heavies had been diverted against targets in NW Europe as part of the softening-up process in preparation for the invasion of Normandy. The landings themselves, on June 6, 1944, prompted an immediate reaction from the Luftwaffe. Within hours of the first Allied troops storming ashore, nearly every single-engine fighter unit engaged in the defence of the Reich was on standby for transfer to a pre-arranged airfield in northern France. Most completed the move over the course of the next two days.

For many it would be a one-way trip. Before the month was out nearly 300 Luftwaffe pilots would be reported killed or missing on the invasion front. Units skilled in the art of tackling high-altitude bombers were sent out on near-suicidal low-level fighter-bomber missions. Bombers and torpedo-bombers rushed northwards from the Biscay and Mediterranean coasts were mauled equally savagely. The Allies enjoyed total air supremacy. Luftwaffe machines were shot out of the sky and bombed on the ground.

The outcome was never in any doubt. When Allied ground forces finally broke out of the Normandy bridgehead, the survivors of those Luftwaffe units still fighting in France were withdrawn to the homeland for rest and re-equipment. The invasion of Normandy had not just set in train the liberation of France, it had also effectively emasculated the carefully-structured Defence of the Reich organisation. Those units returning to ops in the autumn of 1944 were but shadows of their former selves. With many experienced veterans either killed or wounded in France, their ranks were filled with sketchily-trained youngsters who would prove no match for the growing might of the opposition.

Loading up an Fw 190A fighter-bomber with what appears to be an AB 250 missile container (contents: anything from 17 x 22lb to 224 x 2.2lb anti-personnel bomblets); Russian Front, believed to be in early 1943.

The rot sets in

The situation on the Eastern Front was, if anything, even worse. Since the surrender of the 6th Army at Stalingrad in February 1943 German ground forces had been in a state of almost continual retreat. An attempted counter-offensive at Kursk on the central sector

Below: Heinkel He 111s operated by the Romanian Air Force getting ready to take-off from a base in southern Russia, 1942. (Bundesarchiv BA Bild 101I-622-2960-35A)

The Russian Front in the summer of 1943 – a cannon armed Ju 87 is being prepared for another sortie. (Bundesarchiv BA Bild 1011-655-5976-04)

in July 1943 had been broken off prematurely. The fighting around Kursk, which resulted in the greatest tank battle in military history, also witnessed one of the largest gatherings of Luftwaffe close-support aircraft at any time in the war.

But Kursk was to be the final swansong for the venerable Ju 87 Stuka, which had begun its operational career in Spain in 1937. From this point onwards, Stuka units would begin converting to Fw 190 ground-attack aircraft and soon – with the exception of a few dedicated Ju 87 tank-buster squadrons – the Stukas on the Eastern Front, like those in every other theatre, would be relegated to flying night ground-assault missions.

It was the ground-attack units, amalgamated into a separate arm of the Luftwaffe in October 1943, that would bear the brunt of the Eastern Front fighting during the closing 18 months of the war. Equipped almost exclusively with Fw 190s, but with a handful of twin-engine Henschel Hs 129 squadrons numbered among them, theirs was the unenviable task of trying to stop the hordes of Soviet tanks now bearing down on the Reich's eastern provinces.

It has been estimated that when Germany's territorial gains had been at their greatest and the Eastern Front stretched nearly 3,000 miles from the Arctic Ocean down to the sub-tropical Black Sea, the Luftwaffe would have needed to have been four times its actual size to fulfil all its operational commitments. Now, by the beginning of 1944, a tenfold increase would not have sufficed against the Soviets' overwhelming superiority in air and ground forces. Oberst Hans-Ulrich Rudel, the Luftwaffe's most successful tank-killer and the highest decorated officer in the whole of the German armed forces, put it more succinctly: "We were no more than a boulder, a small obstruction but completely unable to stem the tide".

The Red Army's great summer offensive of 1944 far exceeded the Normandy landings in scope and magnitude. It paved the way for the advance through Poland and beyond, to the very centre of Berlin. The Eastern Front's ground-attack units, often operating in conjunction with the last remaining fighters in the area, would contest the enemy's progress until the end.

By now Germany's forces were under pressure from all four points of the compass. In the far north, army and Luftwaffe units stationed in the Arctic – by far the most stable sector of the entire Eastern Front – were forced to withdraw after Finland formally ended hostilities against the Soviet Union in September 1944. Part of the small Luftwaffe presence retired into northern Norway before being transferred to the Berlin front in the closing weeks of the war.

In the Mediterranean many of those Luftwaffe units which had been evacuated from North Africa in the spring of 1943 were based first in Sicily and then on the Italian mainland. Together with a token force stationed in the Aegean and Balkan regions, they formed the first line of aerial defence along what Winston Churchill called the "soft underbelly of Europe". But they were unable to prevent the Anglo-American landings at Salerno and Anzio. And when the Allied advance up the leg of Italy slowed to a crawl, Luftwaffe forces in the area were systematically stripped of almost their entire front-line strength to shore up other, more endangered or important theatres. By April 1945 there were only some 80 serviceable Luftwaffe aircraft left in the whole of northern Italy. Three dozen of them were night ground-attack Ju 87s and Fw 190s; the rest were reconnaissance machines.

Focke-Wulf Fw 190s were used extensively by the fighter units defending the homeland from American daylight bombing raids. These examples are seen at a French airfield in 1943. (Bundesarchiv BA Bild 1011-619-2664-07)

THE FINAL SHOWDOWN

In the West too, where the Allies had long broken out of the Normandy bridgehead and were now closing in on Germany's borders, the Luftwaffe could offer little more than ground-attack opposition, flying operations both by day and night. The few Western-based bombers – the survivors of Steinbock – were notable by their absence. Even the fighter units of the rebuilt Defence of the Reich organisation – the

last cohesive and relatively intact command remaining to the Luftwaffe - were not going up against the American heavy bombers with quite the same frequency and in as many numbers as before. The reason for this reduction in activity is only partly explained by the ever-worsening fuel situation. The Luftwaffe's General of Fighters, Adolf Galland, was deliberately husbanding his strength for one 'Big Blow' which, he hoped, would temporarily paralyse the American daylight bombing campaign and gain a few weeks' breathing space for the defenders.

In the event, Galland's knock-out blow was never delivered. It was overtaken by Hitler's even more grandiose plans for a surprise ground counter-offensive through the Ardennes. Once again the Reich's Defence fighter units found themselves thrust into a tactical role supporting the ground troops engaged in the Battle of the Bulge. But they did not suffer the same high rate of casualties as they had done in Normandy. The bad weather over much of NW Europe at the start of the Ardennes counter-offensive kept many Allied squadrons pinned to the ground.

The end for the Luftwaffe's fighter arm came shortly after daybreak on January 1, 1945, when, much to Galland's fury, over 900 of his fighters were dispatched – not to attack a high-flying US bomber stream – but to carry out low-level raids on the Allied tactical air forces' bases in the Low Countries and France. The result was a disaster. Although the Allies lost some 500 aircraft destroyed or damaged, these could be replaced with relative ease. The attackers' casualties of 271 fighters and 213 pilots lost, with more than 10% of the latter being experienced and irreplaceable formation leaders, was a blow from which the Luftwaffe had neither the time nor the resources to recover.

There would be one last major confrontation between the Luftwaffe and the Eighth Air Force in mid-January 1945 which cost the former another 139 pilots killed or wounded. After that the Luftwaffe virtually relinquished the skies of the Reich to the Western Allies and transferred eastwards to the Berlin front where, for the final three months of the war, they sought to contain that most feared enemy of all: the Red Army.

For much of World War Two the Luftwaffe operated types which had first seen action with the Legion Condor in Spain. The Bf 109 fighter is the prime example, and the He 111 bomber formed an integral part of the bomber arm until its final decline in 1944. Even the Ju 87 Stuka remained in action right up to the end in its specialist nocturnal and anti-tank guises. The other two mainstays of Luftwaffe operations – the Fw 190 series of fighters and ground-attack aircraft, and the multi-role Ju 88 – were both pre-war designs. The Luftwaffe operated many other types, of course; some successful, others very much less so.

But it was not until towards the close of hostilities that a whole raft of new designs began to enter service. Foremost amongst these were the jets. Numerically the most important, and the first to see action, was Willy Messerschmitt's Me 262 twin-jet fighter and fighter-bomber. But by the war's end it equipped just two fighter units, and much of the Luftwaffe's defunct bomber force was still awaiting conversion on to the type.

Messerschmitt was also responsible for the far less successful Me 163 Komet rocket fighter. And whereas Heinkel's single-jet He 162 'People's Fighter' was primitive in the extreme, Arado's twin-engined Ar 234 jet bomber and reconnaissance aircraft was a design of huge potential. But good, bad or indifferent, none of these eleventh-hour additions to the ranks of the Luftwaffe could save it from ultimate defeat. They were all "too little, too late". ■

The Ju 188 also took part in Operation Steinbock – this II./KG 66 example is seen at Arnhem, Holland in 1944. (Bundesarchiv BA Bild 1011-497-3502-20)

Left: Bf 110s fly low over Budapest in 1944. (Bundesarchiv BA Bild 1011-669-7340-27)

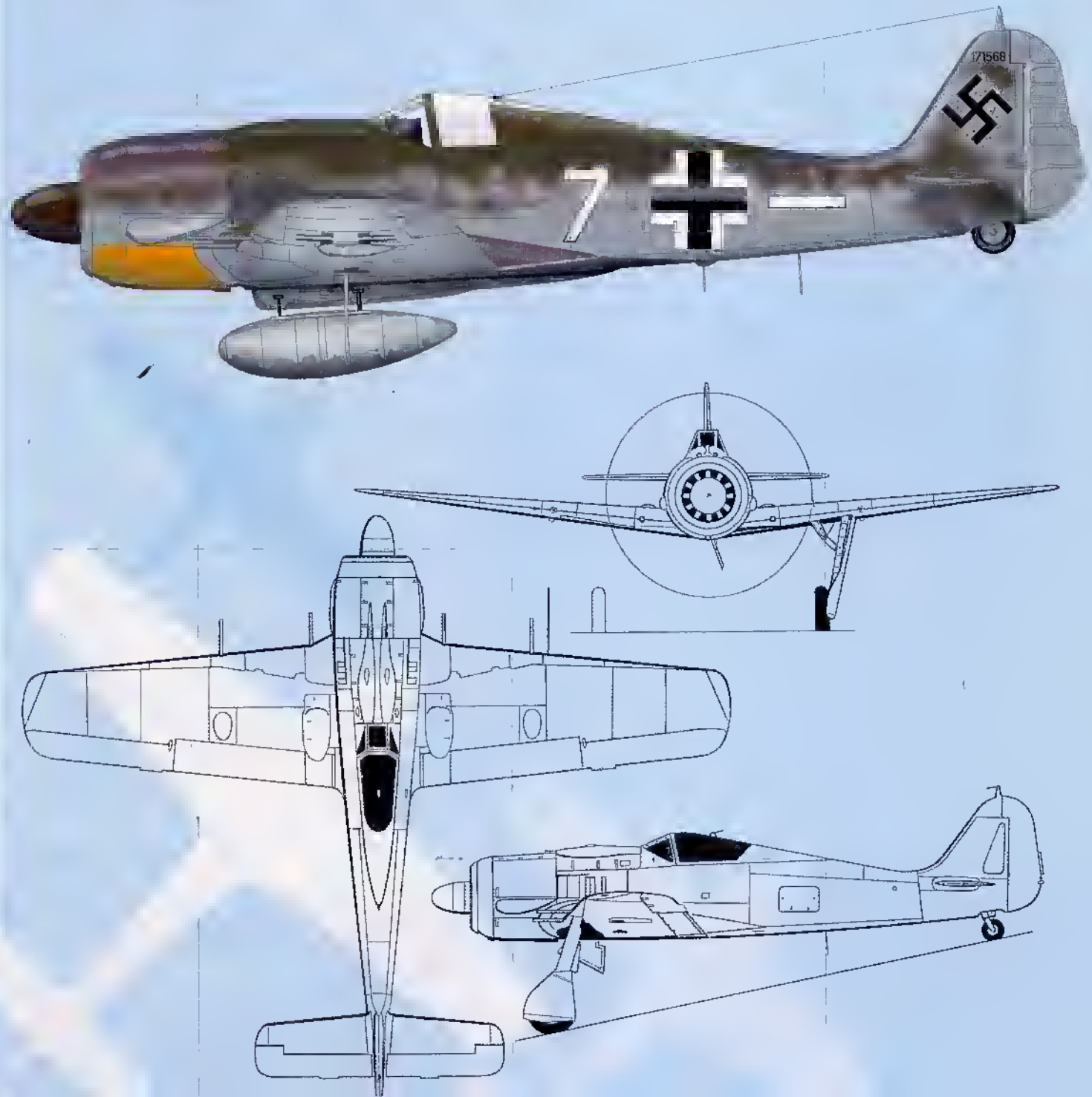
The jet-powered Messerschmitt Me 262 was a revolutionary aircraft. However, Hitler's insistence that it be used as a bomber instead of a fighter cost the Luftwaffe dear, and by the time it was used in the role it had been designed for, it was too late. (Bundesarchiv BA Bild 141-2497)

Widely considered to be the best German piston engine fighter of World War Two, the Fw 190, designed by Kurt Tank, went against Luftwaffe convention at that time, which favoured liquid-cooled engines. A BMW radial powerplant was chosen – initially the BMW 139 – but this was quickly replaced by the heavier, larger and more powerful BMW 801.

The new fighter entered service with 6./JG 26 at Le Bourget in Paris in August 1941 and its first combat experiences against the British Spitfire Mk.V showed it to be superior. Development of additional variants was rapid, though the A series represented the vast bulk of production. As with many other Luftwaffe aircraft, numerous sub-variants were introduced in order to distinguish between different armament and engine installations as well as between fighter and fighter-bomber versions. The Fw 190 was indeed used as a fighter-bomber (some aircraft were fitted with additional armour protection for the pilot), and proved very effective. Early models were armed with four 7.9mm machine-guns, two in the top of the engine cowling and two in the wing roots, all firing through the propeller arc. This was soon found to offer insufficient firepower and so the wing root machine guns were replaced by 20mm cannons. A multitude of other armament configurations were subsequently used, determined by the aircraft's role – fighter or fighter-bomber. The fighter-bomber could carry a single bomb under the fuselage, typically a 550lb (250kg) or 1,100lb (500kg) device.

The aircraft was quickly given the nickname 'Butcher Bird' by Allied pilots, and in experienced hands it was very effective and difficult to defeat. Even as the war progressed and better Allied fighters were introduced, the Fw 190 continued to evolve in tandem and never fell behind on performance.

Fw190A-8, white 7 of 5./JG 26, as in September 1944. (David Howley)



An Fw 190A-3 of I./JG 1 (note the Tatzelwurm insignia on the nose) runs up at a base in France during 1942. This model is fitted with cannon armament outboard of the main undercarriage, a mixture of six machine guns and cannons was the most used combination. From late 1942 the Luftwaffe was to face increasingly large daylight raids by the USAAF and the Fw 190 was to play a major part in the defence of the Reich.
(Bundesarchiv BA Bild 101I-361-2193-25)

Left: The cockpit of the Flug Werk's immaculate new-build Fw 190A-8 D-FWWC.
(KEY - Duncan Cubitt)

Almost 20,000 Fw 190s were built and the type was used extensively by the Luftwaffe, notably in defence of the homeland against the American daylight bombing offensive and also widely on the Russian front.

Liquid-cooled engines were eventually used in the Fw 190. The D model was fitted with the in-line Jumo 213 - to accommodate this the fuselage was lengthened and the size of the tail fin increased. This variant, which entered service in late 1943, and the subsequent Ta 152 version offered very high performance at altitude: the Ta 152H could reach 472mph (760km/h) at 41,010ft (12,500m).

SPECIFICATION

Fw 190A-8

Wingspan	34ft 6in (10.5m)
Length	29ft (8.84m)
Height	13ft (3.96m)
Gross Weight	10,800lb (4,900kg)
Max Speed	408mph (645km/h)
Service Ceiling	37,400ft (11,410m)
Range	950miles (5,120km)
Armament	2 x 13mm machine-guns 2 x 20mm cannon plus option of two more or 2 x 30mm cannon
Powerplant	1 x BMW 801 D

Flug Werk's Fw 190A-8 D-FWWC undergoes engine runs at Manching before making its public debut flight on October 29, 2004. Flug Werk is currently manufacturing 13 new-build aircraft for a number of customers: more details can be found in the January 2005 issue of *FlyPast*.
(KEY - Duncan Cubitt)

THE BOMBE

ARGUABLY MORE THAN ANY OTHER AIRCRAFT TYPE, THE BOMBER HAD THE GREATEST IMPACT ON THE OUTCOME OF WORLD WAR TWO. IT BROUGHT WITH IT A COMPLETELY NEW KIND OF WARFARE, AND ULTIMATELY DELIVERED THE DECISIVE BLOW THAT FINISHED THE CONFLICT.

During the 1930s Germany rapidly expanded its aviation industry and a number of new types, spuriously claimed to be a new commercial aircraft, were developed for the Luftwaffe. Illustrated is the Dornier Do 17, a fast medium bomber that at the time could out-perform many fighters. (KEY collection)

During the First World War the fledgling air forces that did battle over northwest Europe began to experiment with aerial bombardment. Initially the bombs were simply dropped over the side of the aircraft by hand but it was not long before bomb racks were developed so that heavier weapons could be carried beneath the wings or fuselage. Although the Germans undertook some bombing raids on Britain, for the most part the bomber was used to attack enemy troops and lines of communications in and around the battlefronts.

Between the wars and in particular during the 1920s there was little development of the bomber concept. However, the 1930s saw the rise to power of the Nazis in Germany and soon the Luftwaffe was being strengthened in readiness for a new kind of conflict - Blitzkrieg ('lightning war' - see pages 10-15). In the mid-1930s Germany was able to try out its new equipment during the Spanish Civil War with its Condor Legion, which flew alongside the nationalist forces of General Francisco Franco. Other nations quickly realised the threat posed by Germany and started developing new bombers of their own - initially light or medium bombers but larger heavier types were also planned.

LIGHTNING WAR

When Germany invaded Poland on September 1, 1939, it unleashed the Blitzkrieg concept. Rapid advances by mechanised ground forces were supported by massive numbers of aircraft, which targeted key enemy strong points, communications lines and troops. It was the co-ordination of these resources that made Blitzkrieg possible and also very difficult to defend against.

At the start of the war the Luftwaffe had a mixture of light and medium bombers, such as the Junkers Ju 88, Dornier Do 17 and Heinkel He 111, and the Ju 87 Stuka dive-bomber. The latter was a highly effective weapon for as well as accurately bombing individual targets, it was fitted with sirens that screamed as it went into the attack thus adding an element of psychological terror. As the stain of Nazi conquest spread east through Poland, and then north and west into Denmark, Norway, Holland, Belgium and France, these aircraft continued to play a vital role.

With little resistance offered up by these European countries, it was left to Britain to try to inflict some damage on the enemy in the early months of the war. However, the RAF was only equipped with light and medium bombers - the Vickers Wellington being the largest. Although the Wellington did reach Berlin it could only carry a 4,500lb (2,041kg) bomb load.

When Hitler turned his attention to Britain in the summer of 1940 the mighty Luftwaffe suddenly found itself up against a much more organised and resourceful opponent. Blitzkrieg had worked by quickly overwhelming the enemy, but now the Luftwaffe was being asked to gain air superiority before ground forces were committed. Operating from French airfields the Luftwaffe's fighters had limited endurance over southern Britain, and with the aid of radar and careful use of resources, RAF Fighter Command was able to fend off the Luftwaffe onslaught. Even with fighter escort, the Luftwaffe bombers took heavy casualties, and for the first time the slow unwieldy bombers were left

The Fairey Battle light bomber saw action with the RAF during the Battle of France but was easy prey for the Luftwaffe Messerschmitt Bf 109s. (KEY/Gordon Swanborough collection)

ER'S WAR

The massive bomb bay of the Avro Lancaster could carry the largest warload of any wartime heavy bomber. Here an inert 4,000lb (1,814kg) 'cookie' sits under Lancaster I W4783 *G-George* in the Australian War Memorial. (KEY - Duncan Cubitt)

Above: **The Junkers Ju 87 Stuka dive-bomber was a very effective weapon - it was also fitted with a siren that emitted a terrifying scream during a high-speed dive - an early example of psychological warfare.** (Bundesarchiv BA Bild 1011-630-3561-27A)

Above right: **Adding to the RAF's problems... some of its aircraft occasionally fell into German hands, relatively intact. This Wellington is a good example and was repaired and flown by the Luftwaffe to determine its performance and capabilities.** (Bundesarchiv BABild 1011-72-19-88)

vulnerable to fast modern day-fighters.

Changing Tactics

At the same time, the RAF was experiencing similar losses amongst its light bombers sent on daytime raids to targets in northern occupied Europe. The end result was that both the RAF and the Luftwaffe switched the majority of their bombers to night operations. Whilst this provided better protection against the fighters, there was the added difficulty of finding a target hundreds of miles away in total darkness and often in bad weather. Coastal targets were easier to locate, as it was possible to pick out a coastline and recognise landmarks even in the dark - which is partly why the Luftwaffe proved so effective against London, its pilots could reach it simply by flying up the River Thames.

By the summer of 1941 Hitler had turned his attention east to Russia and once again his bombers played a major role helping his armies advance east towards Moscow. But from 1942 Germany began to face an increasing number of attacks from Allied bombers based in the UK. The Americans were now in the war, and together with their British counterparts, they were set to unleash the full potential of the bomber against the Nazis.

Changing Targets

For the most part, up until the Battle of Britain, both sides in the conflict had restricted bombing raids to specific military targets or targets of value to the military, such as roads and railways. Since all of the weapons used were free-fall 'dumb' bombs, accuracy was not guaranteed and so civilian casualties, nowadays referred to as 'collateral damage', were inevitable. But when a Luftwaffe bomber reputedly became lost in the darkness during August 1940 and released its load over London, the RAF hit back with a raid on Berlin. Hitler vowed to wipe out British cities in response and so the Blitz began against the British capital in the late autumn of 1940. For 76 nights the German raiders bombed London, causing widespread devastation and claiming 20,000 lives, the vast majority civilians.

This change in Nazi tactics led RAF Bomber Command to take a similar line, and once it had received sufficient new aircraft it increased the intensity of its night raids against German targets. However, from May 1940 Bomber Command was able to hit strategic industrial targets following the lifting of a political ban on hitting targets in Germany itself. The term 'area bombing' was coined to describe the method employed under the leadership of Air Marshal Arthur Harris, who wanted to 'de-house' much of Germany's workforce and demoralise its people. That said, targeted cities usually fell within the industrial Ruhr area, as well as Berlin and other strategic centres.

In early 1941, Bomber Command was directed to hit oil industry targets, since this was seen to be one of the most effective ways of diminishing the enemy's ability to wage war. However, the Battle of the Atlantic was in full swing and by March, Bomber Command had a new directive to attack U-boat facilities. Such changes to target priorities continued throughout the war to meet the needs of Allied commanders and to respond to adaptations by the enemy. By mid-1941 Bomber Command strength had grown to 49 squadrons of around 18 aircraft each. The airfield construction programme was in full swing with new bases springing up at an incredible rate. New weapons were also available, notably the 4,000lb (1,814kg) 'cookie' blast bomb.

Above: **A 10 Squadron Armstrong Whitworth Whitley at RAF Leeming is readied for an operation in 1941. By this time the type was slowly being replaced by the first four-engine bombers, but it continued to carry out leaflet-dropping missions over Germany for many months.** (KEY/Gordon Swanborough collection)

The Bristol Blenheim was extensively used by RAF in the early months of the war but despite its capabilities it was still very vulnerable to enemy fighters. (KEY collection)

An 83 Squadron Avro Manchester and its crew at RAF Scampton, probably in early 1941. The four-engine Avro Lancaster was developed from the Manchester. (KEY collection)

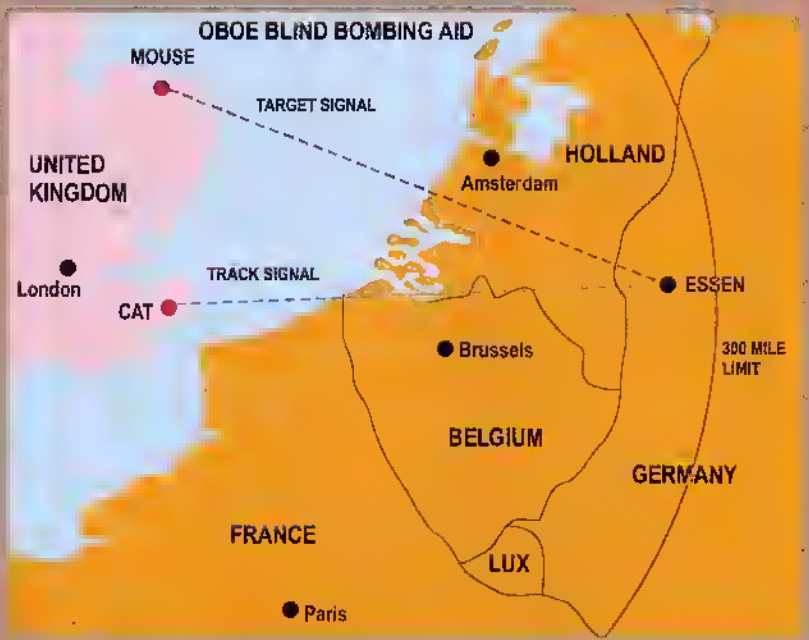
The first of RAF Bomber Command's four-engine heavies was the Short Stirling. Although it lacked the performance of either the Halifax or Lancaster it nevertheless played a crucial part in the bombing offensive between 1941 and 1944. (KEY collection)

A Merlin-engined Halifax gets airborne - the Merlin was used to supplement the more usual Bristol Hercules that powered most examples of the type. The Halifax is often overshadowed by the Lancaster but it made a huge contribution to Bomber Command's night offensive. (KEY collection)

HEAVY BOMBERS

RAF Bomber Command had seen the need for a more potent force before hostilities even commenced. As a result Britain's aircraft manufacturers set about designing new heavier types in the late 1930s to meet the RAF's expansion plans for Bomber Command - aircraft that would be able to carry a more destructive warload over longer distances. Three bomber designs were chosen for production, the Short Stirling, Handley Page Halifax and the Avro Lancaster.

The first of these to enter service was the Stirling, a complex aircraft that relied more on



NAVIGATIONAL AIDS

Beginning in the autumn of 1940 both sides began experimenting with navigational aids, such as radio beams, to guide aircraft more accurately to their targets. The Germans were the first to use this method and although the early equipment was fairly crude, it did allow them to find a target at night. The system, called Knickebein ('crooked leg'), used two beams transmitted from two widely separated locations. These intersected over the target and all the bomber pilot had to do was fly along one beam until he detected the signal of the second beam on a different frequency, then he knew he was in the right place. However, it was quite easy to divert these beams or even create false ones, and quick work by Dr R V Jones and his fellow British scientists of the Telecommunications Research Establishment (TRE) soon disrupted the German beams by various means of jamming and other interference.

The Luftwaffe's infamous raid on Coventry of November 14, 1940, was made possible by the use of another system called X-Gerael, which was more advanced, although it worked on the same principle as Knickebein. A specialised unit, Kampfgruppe 100 (KG 100), acted as a pathfinder squadron equipped with X-Gerael receivers and was a key component in the Luftwaffe's night offensive. It did not take the British long to adapt their jammers to the new beam's frequencies and by January 1941 X-Geraet had been rendered useless.

A third system called Wotan 1 (a one-eyed mythical god) was also used briefly and relied on just a single beam. This was more complex, since the aircraft navigated along the beam but a reradiated signal on a slightly different frequency was used to establish the aircraft's range from the source - hence it could work out when it was over the target. Again a prompt response from the British soon countered this threat.

Bomber Command had some tricks of its own to help it find distant, blacked-out targets at night. The first of these was called Gee, or AMES Type 7000, which became operational in March 1941. This comprised a master and two slave transmitters radiating periodical pulse signals as a four-part cycle. The system generated a series of curves or hyperbolas that could be superimposed over a map to give the location of the bomber. Gee may not have been very precise, but it was better than nothing, and if the target was a large city then it was usually good enough. Over time it was gradually improved but although it was soon replaced by other aids for offensive operations it continued to be used in Britain for training purposes for many years. The Germans did not develop countermeasures for Gee until 1943.

However, a much more accurate system was needed and so the British developed Oboe or AMES Type 9000 which was used by the specialised Pathfinder units to locate a target and then mark it with coloured flares. Oboe made use of radio transponder technology. Two transmitting stations at well-separated locations sent a signal to the pathfinder aircraft fitted with a radio transponder. The transponder reflected the signals back to the two stations and the time each signal took to make the return journey gave the distance to the bomber crew. Oboe stations used the radio ranging to define a circle with a set radius, and the intersecting point of the two circles was set over the target. The Pathfinder aircraft simply flew along the circumference of one of the two circles (referred to as the 'Cat') and dropped its marker flares when it intersected the circle from the second station (referred to as the 'Mouse'). Oboe was extremely accurate and had an error radius of just 110 yards (100m) at 250 miles (400km) range. Its main drawback was that it could only be used by one aircraft at a time. To overcome this problem the British developed Gee-H, which was essentially Oboe but reversed - the transmitter was in the aircraft and the ground stations were equipped with the transponder, thus enabling multiple aircraft to use the system.

A waist gun mount and the ventral Sperry ball turret of a preserved B-17 illustrate the cold confines in which the Flying Fortress gunners had to operate. The heroism of the American crews in the face of marauding enemy fighters during those almost suicidal daylight raids cannot be understated. (KEY - Duncan Cubitt)

The Consolidated B-24 Liberator played just as big a part in the American bombing offensive as its more famous cousin the B-17. Both types flew missions with the Eight Air Force, as well as with the 15th Air Force from Italy attacking Nazi territory from the south. (KEY - Duncan Cubitt)

The Stirling joined the action in February 1941, but while it could carry up to 14,000lb (6,350kg) of bombs, it was not terribly fast and could only reach an altitude of 18,000ft (5,480m). As the war progressed so the Stirling was relegated to other duties, such as glider towing.

The Handley Page Halifax, another four-engine bomber, entered service in March 1941. Though it had a similar carrying capacity to the Stirling (up to 14,500lb [6,580kg] of bombs), it was able to operate up to 24,000ft (7,315m) and had a maximum range of around 3,000 miles (4,828km).

The final Bomber Command 'heavy' was the most famous of all - the Avro Lancaster, which entered service in 1942. It could reach an altitude of 24,500ft (7,468m) and had a range of 2,530 miles (4,072km) with a 7,000lb (3,175kg) bomb load, although a more typical load was a 14,000lb (6,350kg) mixture of high explosives and incendiaries over a shorter distance. Some aircraft were later modified to carry the 22,000lb (9,979kg) Grand Slam 'earthquake' bomb used in the final months of the war.

While Bomber Command was getting to grips with its new equipment, it was joined by another force - that of the United States Army Air Force (USAAF) following America's entry into the war in December 1941. From 1942 the USAAF Eighth Air Force began to establish itself in Eastern England in readiness for the bombing offensive against Germany. This was to be a combined effort with the RAF flying by night and the Americans by day. Many, particularly the British, considered the latter course to be suicidal, based on past experiences of the Luftwaffe and RAF. However, the Americans remained convinced that their bombers, the Boeing B-17 Flying Fortress and Consolidated B-24 Liberator, could defend themselves adequately.

The B-17 was indeed well armed, often with a dozen or more .50 calibre machine-guns and armour - but all of this was at the expense of its bomb load - typically just 6,000lb (2,724kg), less than half of that carried by the Lancaster, although the eventual size of the American bomber formations would still deliver a huge tonnage of bombs. However, the B-17 could fly considerably higher - up to 35,000ft (10,670m), and while this put it beyond the reach of the much of the flak, it was still vulnerable to the fighters. Consolidated's B-24 could not fly as high, but had longer range and carried a greater warload of 8,000lb (3,628kg).

Going on the offensive

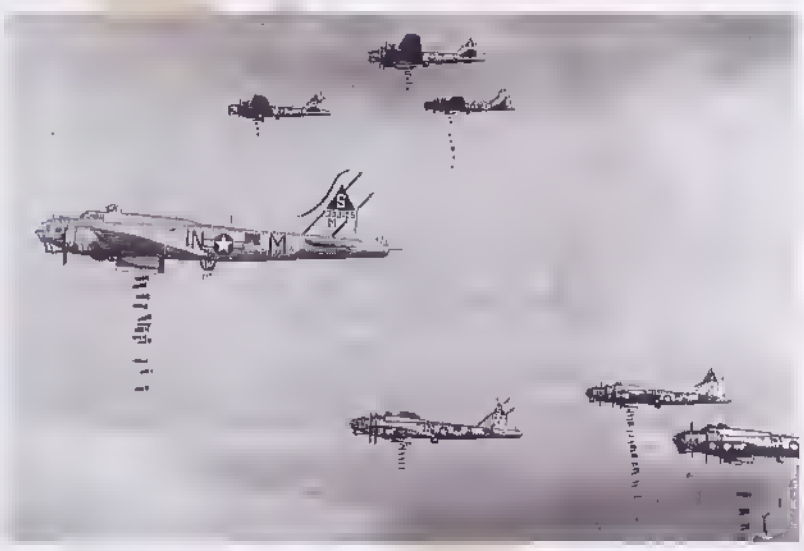
When Air Marshal Arthur Harris took over as head of Bomber Command in February 1942, he was convinced that his force could effectively win the war, provided he had sufficient resources. In May and June 1942, Bomber Command launched three 'thousand bomber' raids against Cologne, Essen and Bremen which were extremely effective, particularly since British losses were kept to a minimum because the enemy's defences had been overwhelmed. If the Command had been able to maintain this level of commitment over a longer period it might well have proved decisive. However, the German defences were improving and RAF loss rates increased.

In August 1942 the US Eighth Air Force began bombing operations in daylight, initially with small numbers of B-17s often with fighters escorting them to targets in occupied France, Belgium and Holland. During 1943 more and more heavy Bombardment Groups began to arrive in the UK, and the Eighth AF was soon able to put up large formations totalling hundreds of bombers. The Americans also began to hit targets deeper into enemy territory, outside the range of friendly escort fighters. It did not take long for the Luftwaffe to concentrate its defensive fighter screen and despite their heavy armament, the American bombers began to take severe losses.

The enemy fights back

British predictions sadly came true as American casualties continued to rise on the daylight raids. One particular raid emphasises the point, the August 17, 1943, mission against the Messerschmitt aircraft factory at Regensburg and the ball-bearing plant at Schweinfurt. By the end of the day, 60 B-17s had been lost, along with 559 men killed or missing in action. Clearly longer range fighter escorts were needed before any more deep penetration raids could be considered. More costly raids did follow though, as commanders were given high-priority targets. On the plus side bombing by day was very accurate, helped by the superb American Norden bomb sight, and so it was left to the Americans to hit pinpoint targets such as aircraft and armament factories, oil facilities, marshalling yards and other strategic targets. At night Bomber Command continued to hit area targets, mostly the large industrial cities of the Ruhr valley.

But even the darkness no longer offered much protection. The Germans had been quick to establish a complex radar network using ground controllers to guide night fighters to engage RAF bombers. Anti-aircraft defences were also



USAAF Eight Air Force B-17Gs of the 401st BG release their bombs over the target. The fact that these aircraft are in their unpainted metal finish indicates this shot was taken towards the end of the war, probably in late 1944. Despite being flown in tight combat box formations, the heavily-armed B-17 still suffered horrendous losses to the German fighters, but that changed when the long-range P-51 escort fighter arrived in early 1944. (KEY collection)

becoming more sophisticated, with radar being used to plot the height and direction of the incoming bombers. Losses on night raids steadily increased and although the Germans were not as successful at jamming the British navigational aids, they were becoming very efficient at locating the bombers in the dark and bringing them down.

To counter this, the RAF introduced a number of new defensive aids, such as Monika to detect the emissions of radar from an enemy night fighter. However, Monika was not a passive system and the Germans turned this to their advantage as it enabled them to locate emitting aircraft. Many other types of jamming were employed by the RAF to try to defeat the enemy's ground-based radars. Some of these were very effective and for the first time used frequency-hopping to confuse the enemy and avoid detection. A good example of this was 'Carpet II' which scanned enemy frequencies to locate an active radar signal, jammed it for 30 seconds and then scanned again – this was highly effective against the German Wuerzburg and Mannheim radars.

This tit-for-tat game of developing new technologies and counter measures continued right until the end of the war. Another element that helped save the RAF's bombers was using its own night fighters to track down those of the enemy.

Overwhelming Numbers

No one factor enabled the Allied bombers to get the upper-hand, it was a combination of technology, numerical superiority and the degrading of the enemy's industrial capacity that turned the tide. By early 1944 the Americans had sufficient bombers to begin launching raids of up to 1,000 aircraft. Most significantly the long-range North American P-51 Mustang was entering service and could escort the bombers all the way to Berlin and back.

The Germans were suffering due to the raids on their munitions and aircraft manufacturing industries and so had started dividing these up and dispersing them to many smaller locations, often underground. Experienced pilots were not being replaced fast enough and as the year progressed so the effects of bombing on the German oil industry really began to be felt. The Luftwaffe was suffering heavy losses to the new P-51, and more and more Allied bombers were making it through to their targets. In the spring of 1944 the Allied Combined Bomber Force (CBF) was put under the control of General Dwight D Eisenhower to support the D-Day invasion of Europe on June 6. But even though this gave Germany-based fighter units a breather, the Luftwaffe could never hope to overcome the shortage of resources and pilots in the face of the overwhelming numbers that they were now facing.

Following the D-Day invasion the bombers returned to hitting high-priority targets such as those facilities producing oil, synthetic rubber, armaments and aircraft. In addition they set out to disrupt the communication networks and the power grid. But it was the damage inflicted on Germany's oil processing plants that ultimately had the biggest impact, this left the Luftwaffe so short of fuel and lubricants that it was impossible to even provide sufficient training flights for new pilots. As a result, many fighter units were effectively grounded by early 1945 and the massive American daylight raids were now meeting very little opposition. To a degree the same applied to the RAF's night operations, which were also benefiting from improved countermeasures – by early 1945 loss rates had fallen to less than 1%.

The Americans also brought a variety of light and medium bombers to all the theatres of World War Two. Here B-25s of the 12th Air Force are seen en route to attack Tripoli in North Africa in November 1942. (US National Archives)

American bomber crews are briefed before another dangerous mission into enemy territory. (US National Archives)

The de Havilland Mosquito, illustrated here by a fighter-bomber version, was known as the 'wooden wonder' for obvious reasons. Yet despite the apparently old-fashioned mode of construction, it could out-perform most German fighters and was one of the most versatile Allied aircraft produced during the war. (KEY collection)

The Pacific

The Americans first made use of their new B-17 heavy bombers in the Pacific immediately after the Japanese attacked Pearl Harbor on December 7, 1941. In the western Pacific B-17s flew missions against shipping and other military targets to try to stem the Japanese advance in the Philippines. As the conflict unfolded, B-17s and B-24s operated from Australia and India against Japanese targets, but never in the massive numbers employed by the Eighth Air Force in Europe.

The introduction of the Boeing B-29 Superfortress played a major part in the eventual defeat of the Japanese Empire. This new highly-advanced bomber entered service in June 1944 and after initial operations from bases in China, the type was based on the Marianas Islands and Guam. From here massive formations of B-29s began to pound Japanese cities with a

The legendary Norden bombsight delivered very accurate results and ensured that the American daylight raids hit their targets effectively. (KEY - Duncan Cubitt)

Germany was convinced its medium bombers were adequate for its needs and so never developed the four-engine bomber with the same determination as the Allies; however, it did produce this aircraft, the Heinkel He 177 in limited numbers. It was powered by two Daimler-Benz DB 610 engines which was the designation given to a pair of DB 605 liquid cooled V-12 powerplants mounted side-by-side. However, its bomb load could not rival that of the Lancaster or Halifax. (Bundesarchiv BA Bild 101I-676-7969OA-25)

Right: The USAAF used a considerable number of light bombers and attack aircraft in tactical roles following the June 6, 1944, D-Day landings. Illustrated is an A-20 Havoc flying low over a heavily-cratered German airfield. (US National Archives)

Far right: The German 88mm flak gun was a very deadly weapon and was used extensively to counter daylight and night-time bombing raids. When it was used with range-finding radar it was even more efficient and claimed a huge number of Allied bombers. (KEY - Duncan Cubitt)

combination of high explosives and incendiaries, killing thousands and causing extensive damage to the mostly wooden buildings. While this had a major impact on Japanese industry, it did not really dent the morale of the people who continued to believe their divine emperor was wholly justified in his actions. The Americans realised a massive show of strength was needed. A force of 851 B-29s - the larges number ever assembled - was sent against Japanese targets on August 1, 1945. Each of them carried up to 20,000lb (9,080kg) of bombs and so the devastation was enormous.

In the end, it was two raids by single B-29s that brought World War Two to a close. On August 6, 1945, *Enola Gay* of the 509th Composite Group flown by Colonel Paul Tibbets dropped a single atomic bomb on the city of Hiroshima. A few days later a B-29 called *Boxcar* dropped a second atom bomb, this time on Nagasaki, and this ultimately led to Japan's surrender (see pages 70-83).

THE MORALITY FACTOR

Strategic bombing had been redefined by the Allies. By late 1944 it was possible for Bomber Command to drop more tonnage on a target in 24 hours than the Luftwaffe had used on London during the whole of the Blitz. The scale of destruction was almost unimaginable with entire cities reduced to ruins. But this and the level of civilian casualties provoked a great deal of controversy in the years after the war. However, it is easy to point the finger after the event... at the time the bomber was the most effective and direct way to hurt the enemy. Demoralising the German population and leaving much of its workforce without homes were viewed as legitimate aims to hasten the end of the conflict.

These days we are all familiar with the capabilities of precision guided munitions to destroy only what is targeted, ideally limiting the number of civilian casualties and reducing conflicts to weeks or months. But World War Two lasted for six years and it must be remembered that many of those people who had been on the receiving end of German aggression felt the heavy bombing was entirely justified.

As for the use of the atomic bombs - well they certainly prevented what was feared would be a very bloody invasion of the Japanese mainland. While casualties in Hiroshima and Nagasaki were high, more people had died in other cities, such as Tokyo, from the use of incendiary bombs which caused huge fire storms. Had the two bombs not been used it is reasonable to speculate that many more heavy conventional raids would have been necessary at a considerably higher cost in human lives.

The bomber completely changed the face of warfare during World War Two. It gave the military the means to strike deep into the heart of the enemy's industrial base. It offered the flexibility to hit key strategic and tactical targets at short notice and its positive effect on morale at home and negative effect on the morale of the enemy must also be considered. While Air Marshal Arthur Harris had not, as he had planned, been able to win the war just by bombing the enemy into submission, it is beyond doubt that the bombers' critical contribution in every theatre of combat shortened the war, probably by years.

American B-29 Superfortresses await the signal to go at Saipan in 1944 for the first large-scale raid on Tokyo. The B-29 was the most advanced bomber to enter service in large numbers during World War Two and it was this type that dropped the two atomic bombs which finally brought the conflict to a close in August 1945. (US National Archives)

One of only two airworthy Lancasters left in the world, the Battle of Britain Memorial Flight's (BBMF) Lancaster I PA474 is a much-loved sight in the UK skies during the summer months.
(KEY - Duncan Cubitt)

The Avro Lancaster was a four-engine development of an earlier twin-engine Avro design called the Manchester. The Manchester, which first flew in July 1939, was powered by two Rolls-Royce Vulture engines, but when but these proved problematical, aircraft designer Roy Chadwick replaced them with four Merlins - and the 'Lanc' was born. The type has since become a legend and an icon of RAF Bomber Command's night-time offensive against the Third Reich.

Armament was provided by three power-operated turrets each equipped with a pair of .303 Browning machine-guns (four in the tail turret). The Lancaster proved to be an extraordinary bomb truck, courtesy of its huge bomb bay and an ability to carry a typical load of 14,000lb (6,350kg). Towards the end of the war, some aircraft were modified to carry the huge 22,000lb (9,979kg) Grand Slam earthquake bomb which was used against targets such as railway viaducts that were difficult to bring down with normal bombs.

The type was involved in many famous missions, but arguably the most well known is the Dambusters raid (Operation 'Chastise') when 19 Lancasters of 617 Squadron attacked the great dams of the Ruhr Valley with the innovative 'bouncing bomb' on the night of May 16/17, 1943. The aircraft leant itself to various modifications to carry non-standard weapons for such missions. Among these was the large 12,000lb (5,443kg) Tallboy bomb that the squadron used to sink the German battleship *Tirpitz* on November 12, 1944, which was still considered a major threat to Allied shipping.

Despite its capabilities and performance, the Lancaster was just as susceptible to enemy action as any other bomber - around half of the 7,377 examples built were lost on operations, and in human terms that amounted to the lives of 21,751 crew members. A handful of Lancasters are preserved in the UK, Australia, Canada and France, but only two remain as airworthy tributes to Bomber Command's war, one in the UK and one in Canada.

The Lancaster cockpit was a fairly straightforward design - it also contained the only piece of armour plate in the whole of the aircraft, the back of the pilot's seat.
(KEY - Duncan Cubitt)

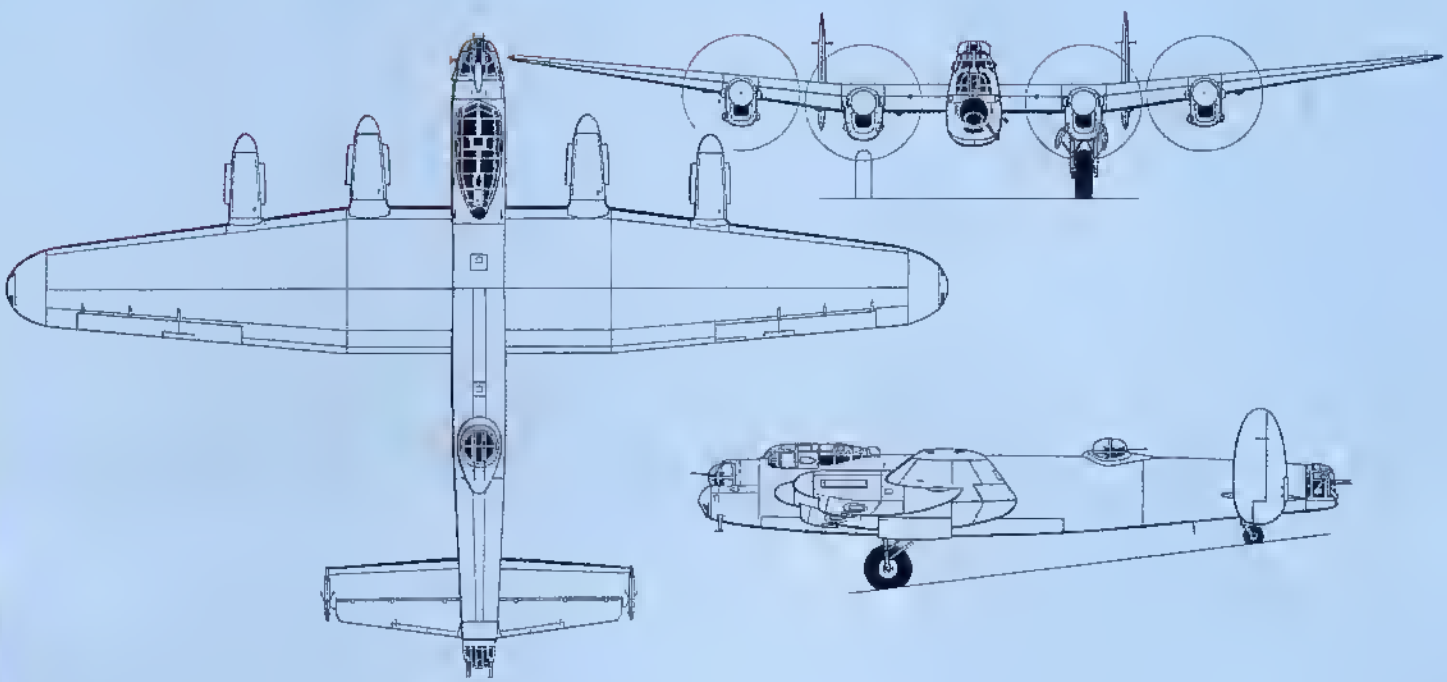
Lancaster I ME844/'LS-W' of No.15 Squadron, which was based at RAF Mildenhall in Suffolk.
(KEY/Gordon Swanborough collection)

Modified Lancaster I (Special) PB996/'YZ-C' of No.617 Squadron equipped with the 'Tallboy' bomb to attack the *Tirpitz*. (Pete West)

SPECIFICATION

LANCASTER I

Wingspan	102ft (31.1m)
Length	69ft 4in (21.1m)
Height	20ft (6.1m)
Gross Weight	68,000lb (30,800kg)
Max Speed	287mph (462km/h)
Service Ceiling	24,500ft (7,468m)
Range	Up to 3,000 miles (4,827km)
Armament	8x .303in machine-guns, up to 22,000lb (9,979kg) of bombs
Powerplant	4 x Rolls-Royce Merlin XX



Of all the bombers of World War Two the Boeing B-17 most clearly evokes the struggle of good over evil. This legendary bomber was developed by the Boeing Company as a private venture - the Model 299 - the aim being to take part in a US Army Air Corps (USAAC) competition for a new bomber that would take place at Wright Field, Ohio, in August 1935. Design work commenced in June 1934, and construction began in August, with the Model 299's first flight taking place on July 28, 1935, at Boeing Field, Seattle, Washington.

The aircraft was eventually ordered into limited production but after Japan attacked Pearl Harbor in December 1941 huge orders were placed for Boeing's big bomber. Eventually production rates would hit 16 aircraft a day, and these were rushed to frontline units.

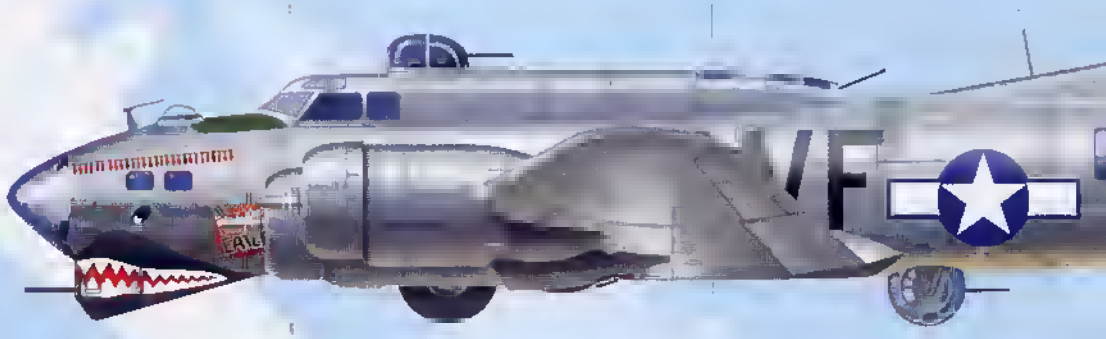
From late 1942 onwards increasingly large formations of these aircraft were flown on perilous daylight raids to targets deep in German-held territory, often at terrible cost to their crews. But equally, the incredible strength of the aircraft did enable some very seriously damaged aircraft to make it back to base.

With its heavy armour and up to 12 machine-guns, the Flying Fortress carried a much smaller bomb load than its RAF counterpart, the Lancaster. But thanks to its very accurate Norden bombsight it was able to hit the mark with great precision and so was primarily used against strategic targets such as aircraft and armament factories, oil refineries, marshalling yards, U-boat pens and the electrical power industry.

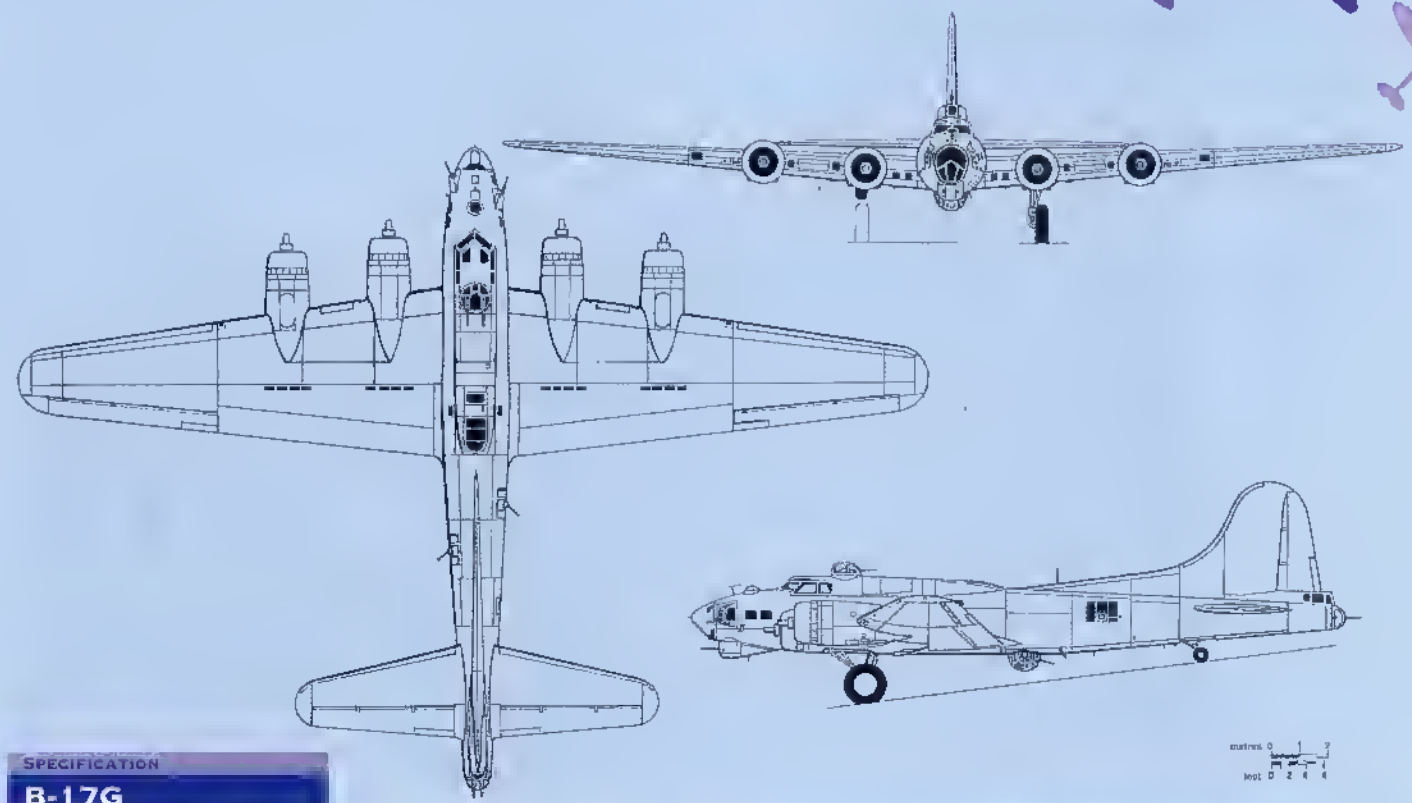
Total production reached 12,731 aircraft, with 8,680 of these being the definitive G model, characterised by its chin-mounted gun turret. In addition to its role with the UK-based Eighth Air Force, the B-17 also saw service in the Pacific, India, North Africa and Italy.

If you want to read more about the B-17, Key Publishing's special magazine titled 'B-17 Tribute' is still available via its mail order department: Key Direct, PO Box 300, Stamford, Lincs, PE9 1NA, UK. Tel: +44 (0)1780 480404; Fax: +44 (0)1780 757812; E-mail: orders@keypublishing.com; Internet: www.keypublishing.com

The sharp end of a B-17G. Early combat experience with the B-17E and F models showed a lack of forward firepower and the Luftwaffe was quick to exploit this with direct frontal attacks. The chin turret went some way towards helping to defend against such attacks. (KEY - Duncan Cubitt)



B-17G-40-DL 44-6009 of the 305th BG. (Pete West)



SPECIFICATION B-17G	
Wingspan	103ft 9in (31.6m)
Length	74ft 9in (22.8m)
Height	19ft 2in (5.79m)
Gross Weight	65,500lb (29,710kg)
Max Speed	287mph (461km/h) at 25,000ft (7,620m)
Service Ceiling	35,600ft (10,850m)
Range	2,000miles (3,218km) with 6,000lb (2,721kg) bombs
Armament	11 · 13 .50 cal machine-guns, max 9,600lb (4,354kg) bombs
Powerplant	4 x Wright R-1820-97 radials

The B-17's cockpit was particularly functional and reasonably roomy, although it would have been a very uncomfortable place during the bomb run as flak shrapnel rattled against the windscreen. (KEY - Duncan Cubitt)

B-17Gs of the 381st BG based at Ridgewell head for another German target. Until long-range P-51 Mustangs became available, these bombers had to fight their way to the target and back through waves of Luftwaffe fighters. (US National Archives)

Radar, in a wide variety of forms, played an increasingly important role throughout World War Two. From its initial use as an early warning air defence system, radar progressed to the air interception and airborne surveillance roles before ultimately being used to aid 'blind bombing'. (KEY collection)

RADAR

A WARTIME REVOLUTION

IAN WHITE, BA (HONS) HIST, IENG, AMRAES, SUMMARISES THE USE OF RADAR DURING WORLD WAR TWO, INITIALLY USED OPERATIONALLY BY THE BRITISH BUT ALSO USED TO GOOD EFFECT LATER BY GERMANY AND THE USA.

Robert (later Sir Robert) Watson-Watt's pioneering work in the 1930s paved the way for the rapid development of radar. (Douglas Fisher Archive)

Following the experiment undertaken by Robert (later Sir Robert) Watson-Watt, Arnold Wilkins and A P Rowe at Daventry on February 26, 1935, radar research and development was centred on the Air Ministry's Experimental Station (AMES) at Bawdsey Manor, Suffolk from March 1936.

With the basic research into early warning (EW) radar more or less completed, Arnold Wilkins was given the responsibility for implementing an installation programme to provide a 'chain' of radar stations around the south-east coast of England.

Under the title of Chain Home (CH) the first station was commissioned at Bawdsey in May 1937, followed by two more at Canewdon and Dover the following August. Following their successful participation in the 1937 air defence exercises, Treasury funding was allocated for an extension of the network to 20 stations. Designated AMES Type 1 by the RAF, CH radar was capable of detecting aircraft at ranges in excess of 100 miles (160km) on four frequencies between 22.69 and 50.5 MHz. By the outbreak of war in September 1939, all 20 stations were operational and on 'watch' and more were under construction to provide a comprehensive electronic barrier around the UK. The CH network was to prove a vital asset during the Battle of Britain.

AIR INTERCEPTION

At the behest of government scientific advisor, Henry (later Sir Henry) Tizard, AMES was tasked with developing an airborne radar set for air interception (AI). In August 1936, the Airborne

Group, under the leadership of Dr Edward (later Professor Edward) Bowen, was established at Bawdsey to design and manage the development of AI radar. The first trials of a complete airborne radar system (transmitter, receiver and display) installed in a Heyford bomber and operating on 6.7 metres (45 MHz), were conducted by Bowen in March 1937. By August of that year, the wavelength, and hence the size of the aerial system, had been reduced to 1.25 metres and installed in Avro Anson, K6260, for flight trials at Martlesham Heath. This set, which demonstrated ranges of two to three miles (3.2 to 4.8km) in the 'sea search', or air-to-surface vessel (ASV), mode and a mile (1.6km) in AI, formed the basis for all the wartime airborne radars. With the wavelength increased to 1.5 metres (200 MHz) to improve the sensitivity, the first hand-built examples of AI Mk.I were installed in six Blenheim IVf fighters of a special flight, No.25 Squadron at Northolt, in August 1939, while similar examples of ASV Mk.I were fitted to a very small number of Coastal Command aircraft.

The first operational AI, AI Mk.III, (Mk.II was a failure) was installed in the Blenheim IFs of Nos.23, 25, 29, 219, 600 & 604 Squadrons in May 1940. The first AI success of the war occurred on the night of July 22/23, 1940, when a Blenheim If of the Fighter Interception Unit (FIU), piloted by Fg Off Glyn 'Jumbo' Ashfield, with Sgt Reginald Leyland operating the radar and Plt Off Morris observing, intercepted and shot down what is believed to have been a Dornier Do 17Z off Bognor Regis, Sussex. The Blenheim/AI Mk.III combinations main disadvantage was the modest performance of the aircraft and the poor minimum range of the radar. In an attempt to overcome the former, Fighter Command's C-in-C, Air Chief Marshal Sir Hugh Dowding, directed that future night-fighters were to be based on the Bristol Beaufighter, which had both the performance and the armament required of a night-fighter. To match this, AMRE called on the assistance of the EMI Company, and particularly the services of its chief designer, Alan Blumlein, to produce the first practical series-production AI radar, AI Mk.IV.

Variations in the quality of radar operators and with it the need for the pilot to control the latter parts of an interception, led to the development of AI Mk.V and the introduction of the pilot's indicator (a small cathode ray tube - CRT) in the cockpit. Installed from April 1942 onwards in the superb de Havilland Mosquito, AI.V claimed its first victim on the night of June 24/25, when a Mosquito NF.II from 151 Squadron destroyed a Dornier Do 217E-4 over the North Sea. The final metric AI radar, AI Mk.VI, a fully automatic system for single-seat fighters, was developed and test-flown in 1942. However, with the removal of single-seat night fighters from Fighter Command's inventory in 1942 and the imminent introduction of centimetric radar technology, AI.VI production was cancelled and the sets were converted to Monica tail-warning radars for Bomber Command.

One of the first, and critically important, uses of radar was in the Chain Home early warning network of the British Isles. This system was a fundamental element in giving the RAF the edge in the Battle of Britain. (Douglas Fisher Archive)

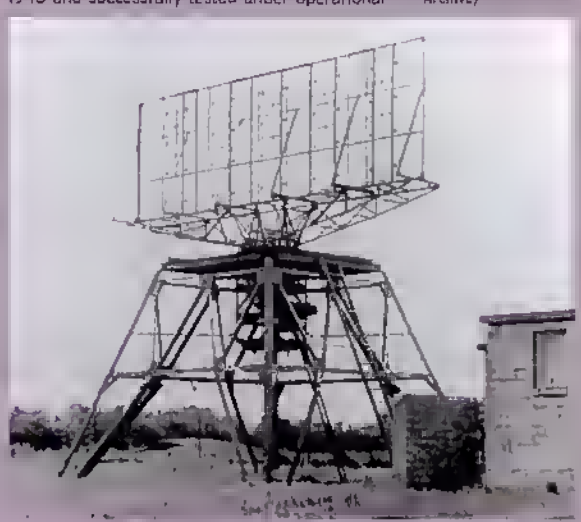
Early AI radars, such as the type fitted to this Mosquito II, featured fixed antenna usually mounted on the nose or under the wings. The move to smaller centimetre wavelengths and the use of moveable radar 'dish' antenna eventually saw the equipment concealed inside special housings. (KEY collection)

GROUND CONTROLLED INTERCEPTION

It was with the Beaufighter/AI.IV combination that Fighter Command began to oppose the night time Blitz of 1940/41 with, albeit in limited numbers. The Beaufighter entered service in September 1940 and scored its first victory on the night of November 15/16, when an aircraft of 604 Squadron destroyed a Junkers Ju 88A-5 near Chichester, Sussex. Overall, Fighter Command's performance in the autumn and winter of 1940 was poor, due in part to the limited number of Beaufighters, a lack of trained aircrews, poor radar serviceability and the defence's inability to track enemy aircraft once they had passed through the CH screen.

This last problem had been foreseen by AMRE, who undertook interception trials earlier in the year, which, in turn, led to the production of a ground control of interception (GCI) radar, based on elements of the 1.5-metre Chain Home Low (CHL) radar, that was designed to fill the low-level gaps in the CH chain, and the Army's gun-laying (GL) radar. With its rotating aerial and plan position indicator (PPI) display, the first mobile GCI (AMES Type 8) was installed at Durrington in November 1940 and successfully tested under operational

An example of the 1.5-metre Chain Home Low (CHL) radar, designed to fill the low-level gaps in the CH chain. (Douglas Fisher Archive)



In the middle of 1940, 12 Lockheed Hudson general reconnaissance aircraft from 220, 224 & 233 Squadrons had been equipped with ASV Mk.I. However, this early version was less than successful. (KEY collection)

Far right: The German Würzburg, built in a number of progressively improved models, proved an extremely useful element in the German early warning system. (KEY collection)

Wellington VIII W5674 equipped with the ASV Mk.II during trials in 1940. This radar was a considerable improvement over the earlier ASV Mk.I. (KEY/Gordon Swanborough collection)

conditions the following month. By April 1941, six Type 8s were in operational service. An improved version, AMES Type 7, that was capable of handling multiple interceptions, was deployed at permanent GCI stations from the summer of 1942.

Anti-shipping role

While Fighter Command was enduring the Blitz, Coastal Command took second place in the supply of radar equipment. However, by June 1940, 12 Lockheed Hudson general reconnaissance aircraft from 220, 224 & 233 Squadrons had been equipped with ASV Mk.I. The ASV.I system suffered from poor range performance, and although useful in bad weather, was inferior to the human eye on a good day. By reducing the frequency slightly from 214 to 176 MHz and introducing a more powerful transmitter and a sensitive receiver, the new system, designated ASV Mk.II, showed a marked improvement in performance. Recognisable by its 'stickleback' transmitter aerials, ASV.II demonstrated a broadside range of 20 miles (16km) against a side-on submarine target and a forward range of eight miles (12.9km), when the aircraft was flying at 2,000ft (610m). The first production ASV Mk.II sets were delivered to Coastal Command in December 1940 and by the following summer most of its GR aircraft were radar equipped.

German developments

Great Britain was not alone in developing radar in the 1930s. Scientists at the German Navy's (Kriegsmarine) Communications Research Establishment at Kiel, led by Dr Rudolf Kühnhold, began their research into radar in 1929 and by November 1938, had succeeded in building the prototype of an EW radar, codenamed 'Freya'. This operated on the 2.4-metre wavelength (125 MHz) and demonstrated a range between 25 and 46.5 miles (40-75km). Faced with the possibility of British bombing on the outbreak of war, the Luftwaffe took over Freya development early in 1939 and placed it in production with the GEMA Company. Production versions of Freya proved capable of detecting aircraft at a range of 75 miles (120km). Another group financed by the Telefunken Company (now AEG) and led Dr Wilhelm Runge, began their research in 1932. By the summer of 1938, Runge's group had built a less powerful, but more accurate radar that was best suited to the control of searchlights and anti-aircraft guns (Flak). Operating on a frequency of 0.5 metres (600 MHz) this radar, codenamed 'Würzburg A', detected aircraft at a range of 64 miles (40km). By 1940 Telefunken introduced Würzburg D, which operated on a frequency of 0.53 metres (560 MHz), had a search range of 19 to 25 miles (30-40km), an engagement range of 11.25 miles (18km), swept 360° in azimuth and angles of elevation up to the vertical. During the early part of the war it was employed in the flak and GCI roles.

German research into ASV radar had matured sufficiently by the end of 1941, thanks in part to the capture of an ASV.I set, for two radars to be introduced to service; Neptune S that gave ranges out to 9.25 miles (15km) against ship-sized targets, and the GEMA developed Rostock that operated on 2.5 metres (120 MHz) and had a range of 18.75 miles (30km). Another company, Lorenz, introduced a third ASV set, Hohenteil, in September 1942, which had a range of 50 miles (80km) against ship targets. Hohenteil went on to become the Luftwaffe's most popular series of ASV radar, with some 500 being built and installed in the Blohm und Voss Bv 138 and Bv 222 flying-boats and the Fw 200, Heinkel He 177 and Ju 290 maritime patrol aircraft. The Siemens company developed a lightweight version of Neptune in 1944, Neptune V, for use in single-seat night-fighters and Neptune R-1 and R-2 tail-warning radars.

Early in 1939, Runge's team had experimented with the design of a radio altimeter under the codename 'Lichtenstein A', and produced a research model by early 1940. Taking elements of Lichtenstein A and combining them with a forward facing aerial array, Runge and his team succeeded in test flying an experimental AI radar in the autumn of 1940. The Luftwaffe High Command's (the Oberkommando der Luftwafle - OKL) distrust of electronic gadgetry and its opposition to externally mounted aerials, delayed the introduction of AI by a year. However, when combined with elements from other radars, Telefunken developed Lichtenstein BC during the summer of 1941 and test flew it in a Dornier Do 215B-5 night-fighter in September. With the Luftwaffe now willing to accept external aerials on its fighters, Lichtenstein BC was committed to production in February 1942 and introduced to service by the Nachtjagd the following spring in the Bf 110F, Junkers Ju 88G and Dornier Do 215B series of night-fighters. Lichtenstein BC operated on a wavelength of 0.6 metres (490 MHz) had a maximum range of 2.1 miles (3.4km). The operator's (bordfunker) display comprised three CRTs displaying range, azimuth and bearing that were fed by signals from multiple dipole aerials in the nose.

The BC set was succeeded by the Lichtenstein C-1 from June 1943. This set was switchable across the frequency range 420-480 MHz to counter RAF jamming, had the displays reduced to two (range/azimuth and range/elevation) and was reduced in weight to 60lb (27kg). Its performance, however, was broadly similar to that of Lichtenstein BC. Telefunken's final Lichtenstein product, SN-2, was developed from the company's Lichtenstein S, ASV radar, and operated in the 37.5 to 118 MHz range. With an output power of 2.5kW, the SN-2 set had a maximum range of 2.5 miles (4km), but a poor minimum range. A sub-variant, Lichtenstein SN-2b incorporated Lichtenstein C-1 to broaden its 'look' angle.

Mindful of the need to improve the ground control of its night-fighters, the OKL called upon Telefunken to develop a radar that could be used

in conjunction with Freya, but had a greater range and bearing accuracy than Würzburg. Two of the company's engineers, Drs Pederanzi and Neubauer, designed a new system and matched it to a 24.5ft (7.5m), power-driven, parabolic reflector manufactured by the Zeppelin company. Designated Würzburg-Riese (Giant Würzburg), this GCI radar worked on the 5.3-metre band (560 MHz) and demonstrated a search range of 37.5 to 50 miles (60 to 80km) and a control range of 31.25 to 37.5 miles (50 to 60km). Built in large numbers from 1942 onwards, it replaced Würzburg D and remained in service until the end of the war.

Fine tuning

The promise of shorter 'centimetric' wavelengths and narrower beams devoid of ground returns became a reality in February 1940, when J T Randle and H A H Boot ran the first resonant cavity magnetron valve at Birmingham University. This device, which some have rightly described as one of the most significant technological developments of World War Two, demonstrated a test-bench pulsed output of 10kW on a wavelength of 9.8cm (3,060 MHz). With the support of GEC, the magnetron was gradually developed to the point where a small number were made available to the scientists at AMRE in May 1940, which had by then moved to Worth Matravers, near Swanage. In great secrecy, a team, initially under the management of Dr Herbert Skinner, was formed to design an AI radar around the magnetron valve, while Dr Bernard Lovell examined the feasibility of building a parabolic dish aerial and installing it in a radio transparent (Perspex) radome fitted to a Blenheim IV.

Designated AIS, where the 'S' stood for 'sentimetric', the new radar employed an eccentric spiral scanning system built by Nash & Thompson Ltd, and range displays, where the target return was shown as an arc. Blenheim N3522 was fitted with the prototype AIS system and test flown from the Telecommunications Flying Unit's (TFU) airfield at Christchurch on March 10, 1941, where it detected an aircraft at a range of 7,000ft (2,135m) when flying at a height of 5,000ft (1,525m) – a task impossible for AI Mk.IV. Further developed and installed in a Beaufighter for trials with FIU, the set demonstrated ranges up to 10 miles (16km), before being committed to limited production (100 sets) in December 1941, as AI Mk.VII. During February 1942, Beaufighters of Nos.29, 68, 141 and 604 Squadrons, were converted to AI.VII, with the radar enclosed in a 'thimble' radome developed by the Bristol Aeroplane Company.

During September 1942, Mosquito NF.II, DD715, was converted to the thimble-nose standard to take AI Mk.VIIIA, the [illegible] production version of

A Luftwaffe Messerschmitt Bf 110G-4/U8 of 6./NJG 6 equipped with an early German AI radar. (Bundesarchiv Bild 101I-778-1105-09A)

219 Squadron's Beaufighters to be converted during January 1943, and record the first AI.VIII kill, a Do 217, on the night February 3/4. During May 1943, 151 Squadron converted to the Mosquito NF.XII, followed by 85 and 488 Squadrons.

American ideas

Devoid of the urgent needs of war, radar research in the United States was not as advanced as that in Europe. However, in exchange for military equipment, ships and bases, Britain provided America with details of its scientific developments through the auspices of the Tizard Mission to Washington in September 1940. One of its 'gifts' was the magnetron. With the assistance of Dr Bowen, the Massachusetts Institute of Technology established its Radiation Laboratory for applied research in the field of centimetric radar technology. Beginning with an experimental design, the SCR 520, built in October 1941, the Western Electric Company developed its SCR 720B AI set, which was made available for testing in Britain in December 1942, alongside the Telecommunications Research Establishment's (AMRE was renamed 'TRE' in November 1940) AI Mk.IX. With the prototype AI.IX lost on December 23, along with its principal designer, Dr Downing, and SCR 720 performing well in the face of Window (chaff) jamming, the Air Ministry took the pragmatic decision to order the American set as AI Mk.X for installation in the Mosquito.

The first AI.X sets were delivered to the UK during December 1943 for installation in Mosquito NF.XVIIs. By the end of January 1944, Nos.25 & 85 Squadrons had completed their conversion and were committed to operations the following month, with No.25 claiming the first Mosquito/AI.X kills on the night of February 20/21. With a range performance that varied between 5.5 and six miles (8.8 and 9.6km), AI.X was to see service to the end of the war and beyond.

Defensive and bombing aids

With the strengthening of the Nachtjagd during 1942, some thought was given to the provision of a rearward facing radar for Bomber Command aircraft. With large numbers of AI.VIs on order, and no apparent use for them, the RAE converted the sets to a rearward looking radar, under the codename Monica. Working on the same 200 MHz frequency as the metric AI radars, Monica gave warning of an aircraft, friend or foe, inside a 45° cone that extended some 1,000 yards (915m) behind the bomber. Signals from an aerial located beneath the rear turret, gave the

Illustrating the 'thimble' type radar housing on the nose, a Beaufighter VIf fitted with the AI Mk.VIII is seen in Italy towards the end of the war. (KEY/Gordon Swanborough collection)

The Americans developed their own 3cm H2X radar, based on the British H2S, and fitted it in a retractable thimble housing beneath B-17s and B-24s. This particular example is a Liberator B Mk.VIII delivered to the RAF. (KEY collection)

The advanced AI.X, based on American research, was fitted to the Mosquito NF.XII. (KEY/Gordon Swanborough collection)

The invention and subsequent military application of radar changed the face of aerial warfare forever. The British developed the H2S radar which showed ground features and was a massive aid in finding targets at night. Its revolving antenna was located in the domed fairing beneath the fuselage of the Lancaster (illustrated) and the Halifax. (KEY collection)

wireless operator (W/Op) an audible warning of the approach of an aircraft, but since these could not be positively identified, Monica was regarded as unreliable by the bomber crews. Being an 'active' device, its signal could also be detected by a suitably designed 'homing' receiver, which Siemens developed under the codename 'Flensburg', following the capture of a Monica set in March 1943. Flensburg had a detection range of some 60 miles (100km) and was used to great effect on Bomber Command's aircraft, until Monica was removed in the summer of 1944.

Although development of the 'Gee' and 'Oboe' area navigation systems were in hand at TRE, Bomber Command also required a blind-bombing device that would enable its bombers to strike in poor weather and in the dark. It was discovered during AIS testing that buildings reflected radar signals better than the ground. By depressing the scanner in the AIS Blenheim, two members of the centimetric team, Dr O'Kane and G S Hensby, demonstrated the radar's ability to 'paint' the ground and highlight the buildings, during a test flight over Southampton on November 1, 1941. Further flights the following month confirmed the findings and set in motion the development of H2S, under the direction of Dr Lovell.

Charged with the design of equipment capable of installation in Bomber Command's four-engined 'heavies' (Stirling, Lancaster or Halifax), Lovell was allocated a Halifax Mk.II, V9977, to act as a test-bed and development aircraft for the new ground mapping radar. V9977 was delivered to TFU at Hurn on March 27, 1942, for the installation of the klystron based H2S prototype, in the aft part of the fuselage, in a ventral position, where a rotating scanner in a Perspex radome was fitted. A second Halifax II, R9490, was similarly modified, but mounted a system built by EMI.

Flight trials with V9977 during April 1942, proved disappointing, due to the low power output of the klystron, but when testing passed to R9490 with its magnetron-based transmitter (following the loss of V9977 on June 7, with its crew and several TRE and EMI scientists) the system's performance increased significantly. Passed to the Bomber Support Development Unit for service evaluation in September, where it received a favourable assessment, H2S was committed to production in the autumn of 1942. Delivered to Bomber Command in its 9.1cm (3,296 MHz) form, in January 1943, H2S Mk.I flew operationally for the first time on the night of 30/31, when Stirlings and Halifaxes of 7 and 13 Squadrons of the Pathfinder Force, marked the city of Hamburg. H2S Mk.III introduced 3cm (10,000 MHz) technology for improved discrimination and later, Fishpond, a device that employed a part of the mapping signal for rearward defence and displayed the output on a separate CRT display, was installed at the W/Op's station.

ASV DEVELOPMENTS

With the prospect of magnetrons operating in the 3cm band, TRE had begun the development of a centimetric ASV set during the summer of 1942. However, with the introduction of the Metox receiver that was able to detect the transmissions from ASV.II and resulted in a subsequent reduction in U-boat kills, the Establishment set about the task of adapting an H2S set to the ASV role. The first trials of the new set, designated ASV Mk.III were undertaken at TFU's Dettord base in December 1942 (TFU moved to Deltord in May 1942 to be close to TRE, which had moved to Malvern). These proceeded reasonably smoothly and by the end of March 1943, the GR aircraft of 172, 224 and 407 (Canadian) Squadrons had converted to the new radar, followed by Nos.58 and 502 during May. Deprived of the warning provided by Metox during the 1943 spring offensives in the Bay of Biscay, 37 U-boats were sighted at night, and one may have been sunk. U-376 may have been the first ASV Mk.III victim on April 10, but U-332 was certainly destroyed by a Liberator of 224 Squadron on April 29. After April, U-boat losses mounted steeply, with the ASV Mk.III equipped aircraft contributing significantly to that victory. Thereafter the initiative in the Atlantic passed back to the Allies and was never lost.

GERMANY CATCHES UP

On the night of February 2, 1943, the German technical intelligence teams were handed a gift in the form of an intact magnetron valve, which they recovered from the crash-site of a Stirling that came to earth near Rotterdam. Armed with centimetric technology, the German electronics

industry began the protracted development of an AI set, which culminated in the design of Telefunken's Berlin radar. Ten sets of the Berlin N-1a type, that operated in the 9 to 9.3cm band and had a range of 3.1 miles (5km), were delivered to the Luftwaffe and installed in Ju 88G-7c night-fighters during April 1945, but none saw operational service before the end of the war.

Development of German ground-based radars, operating in the metric waveband, was not neglected during the middle years of the war. The 'Freya' EW radar was succeeded, but not displaced, by a series of improved radars. The EW Jagdschloss, built by a consortium comprising Gema, Siemens and Lorenz, operated on 2.4 metres (125 MHz), with a range of 50 miles (80km) and 360° coverage. Mammut was a long-range EW radar built by Telefunken and the Luftwaffe Experimental Signals Command, with 100° electronic scanning and a range of 185 miles (300km) and, finally, Wassermann, another long-range EW set built by Siemens, operating on 2.4 metres, with a range up to 130 miles (208km). 'Würzburg' was likewise continuously updated, adapted and improved.

Technological Legacy

While much of the early development of centimetric technology was centred around airborne equipment, the employment of shorter wavelengths offered the possibility of higher discrimination, and hence more accurate radars and an insurance against Luftwaffe 'Window' jamming on the 1.5-metre band ('Window' foil was codenamed 'Düppel' in German scientific circles and was used offensively against British radars in October 1943). In September 1942 TRE set about the task of designing a centimetric GCI, the mobile AMES Type 13 that employed a fan shaped beam, 7.5° in width, and a vertical parabolic reflector. With mechanical scanning in the vertical plane, the Type 13 in its Mk.II form, was placed in production in March 1943 and in service proved to be a very accurate height-finding radar. The need for a similar performance in the horizontal plane (360° scanning) with PPI, led to the development of the AMES Type 14. Operating like the Type 13, in the centimetric band, the Type 14 radiated a very narrow, and hence, accurate beam. The first Type 14 was working at Sandwich GCI in January 1944, alongside a Type 13. Together the two radars constituted the AMES Type 21 installation. By June 1944 most of the important fixed GCI stations were equipped with Type 21 installations. The system was also deployed by the RAF post-D-Day on the Continent and remained in service post-War.

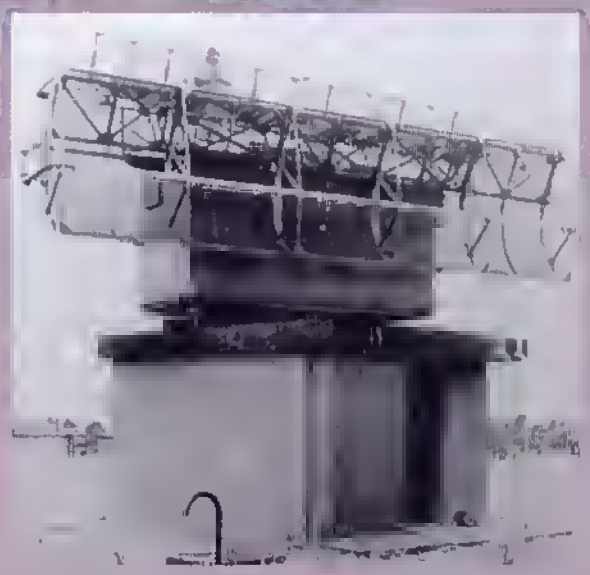
The advent of 3cm technology in 1944 enabled the radar designer to produce even narrower beams and more accurate systems. In the autumn of 1944, Bomber Command introduced

One of the more deadly Allied night fighters of World War Two was the Northrop P-61 Black Widow, which made use of advanced American AI radar technology. (Ken Rust via Warren Thompson)

the Automatic Gun-Laying Turret (AGLT), under the codename 'Village Inn'. This system, first installed in Lancasters of No.101 Squadron, comprised a small parabolic scanner that was located below the turret and 'slaved' to the barrels of the four 0.303inch (7.69mm) Browning machine-guns. The gunner was provided with a small CRT with which to track the enemy night-fighter and engage it, even though he could not necessarily see it – a 'blind fire' capability. 'Village Inn' saw limited use until the end of the war, due to difficulties in operating the system and frequent mechanical failures.

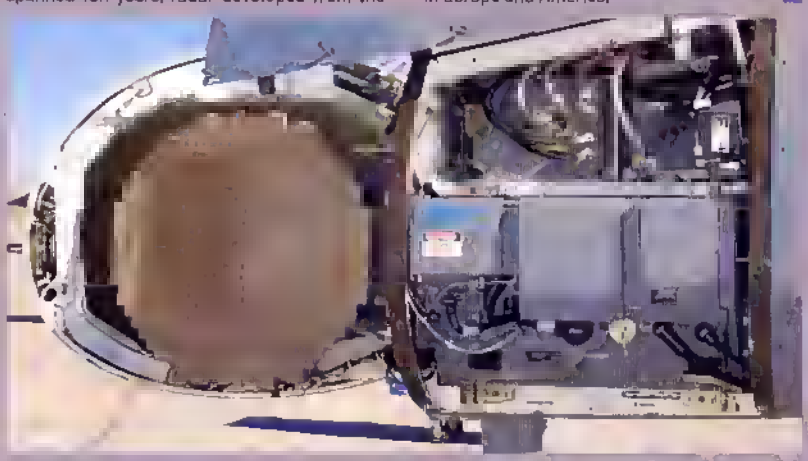
The introduction of the schnorkel on U-boats that enabled them to run underwater on their diesel engines, provided Coastal Command with a problem. The 9cm beam of ASV Mk.III was unable to detect the device, except in good sea states, and consequently, U-boats were able to cruise at high speed and recharge their batteries almost unmolested. During the summer months of 1944, the British evaluated the American 3cm AN/APS-15 radar and adopted it for use as ASV Mk.X towards the end of the year. This radar was a definite improvement on the Mk.III ASV, being able to 'see' the schnorkel mast more easily in all but the worst seas.

Like many other industries during the Second World War, that of radar and radar-related devices witnessed massive strides in technological development and equipment capability in all areas of warfare. Throughout a period that barely spanned ten years, radar developed from the



A requirement for a high performance GCI radar operating in the horizontal plane (360° scanning) with PPI, led to the development of the AMES Type 14. Operating like the Type 13, in the centimetric band, the Type 14 radiated a very narrow, accurate beam. (Douglas Fisher Archive)

metric wavelengths and 1kW radars of the late 1930s to the 3cm wavelengths and tens of kilowatt equipments of 1945. Its deployment by the Allies helped win the Battle of the Atlantic, improved the bombing accuracy of Bomber Command, and from late 1941 onwards, provided Britain with the best air defence system in the world. Post-war the technology was introduced to civil aviation and further improved throughout the Cold War period, and up to the present day, where the integration of miniature electronics and computing power, has delivered radar systems with a degree of power and accuracy undreamt of by the radar pioneers in Europe and America.

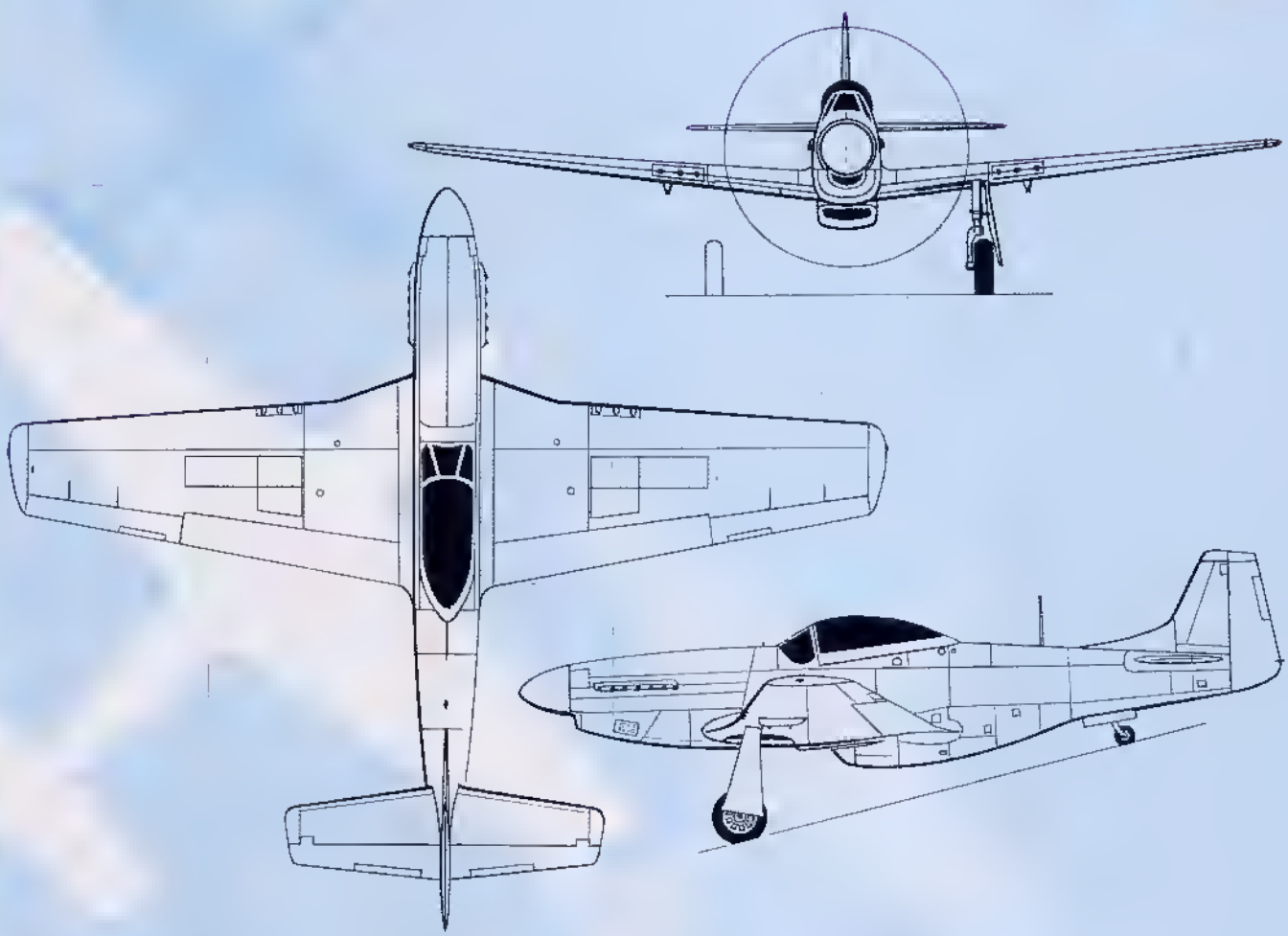


Today's radars, such as this APG-68(V)9 as fitted to a Lockheed Martin F-16, are a world away from the radars of World War Two. The latest electronically-scanned array radar technology can even identify a hostile aircraft from its radar signature at ranges well in excess of 100 miles. (Lockheed Martin)

The clean classic lines of the P-51D Mustang are well illustrated in this air-to-air study. The aircraft ultimately equipped 14 Eighth Air Force Fighter Groups and was a key factor in the defeat of the Luftwaffe over Western Europe. (KEY - Duncan Cubitt)

Universally regarded as an American fighter, the Mustang was actually designed to meet a British requirement for a fast day fighter in 1940. The prototype was designed, built and flown in an amazing 100 days – the first flight occurring on October 26, 1940. The Mustang Mk.I was originally powered by an Allison V-1710 but the performance of the early RAF versions was poor.

At the same time the USAAF was showing interest in the aircraft, so when the British modified the Mustang to accept the Rolls-Royce Merlin engine and consequently boost its performance, the Americans were even more impressed. Furthermore, the type's thin wing also endowed it with excellent speed, low drag and made the aircraft tremendously manoeuvrable.



The Allison-powered Mustang was originally delivered to the RAF, and the early marks featured a high back – typical of fighter design in the early part of the war. (KEY collection)

A P-51D of the 364th FG based at Honington in Suffolk. (Pete West)

SPECIFICATION

P-51 D

Wingspan	37ft (11.27m)
Length	32ft 3½in (9.54m)
Height	13ft 8in (4.16m)
Gross Weight	12,100lb (5,488kg)
Max Speed	437mph (703km/h)
Service Ceiling	41,900ft (12,770m)
Range	2,080 miles (3,347km)
Armament	6 x 0.5in machine-guns
Powerplant	1 x Packard V-1650-7

The Mustang cockpit, like many others of the era, was compact but fairly well laid out. The large canopy, introduced with the P-51D, gave the pilot a superb view, which is essential in air-to-air combat. (KEY - Duncan Cubitt)

The Merlin-powered USAAF P-51B and C models went into production in the USA in 1943; those destined for the RAF were called the Mustang III. These variants began to enter service at the end of the year and soon the US Eighth Air Force was using the new aircraft as a true long-range escort fighter to accompany its bombers to distant enemy targets in Europe. This marked a turning point in the American daylight bombing offensive, which up until this point had been suffering horrendous losses to enemy fighters. The P-51 was soon available in large numbers and the chief production variant, the P-51D, became the prevalent model with American fighter units. Armed with six 0.5in machine-guns, and the range (with drop tanks) to take it all the way to Berlin and back, this aircraft quickly turned the tide against the Luftwaffe in the skies over Germany.

The P-51 also proved to be a very capable fighter-bomber, although the underslung radiator did prove to be a weak point putting the aircraft at risk should it be hit by ground fire at low level.

The F-6 Mustang was used for reconnaissance, while other versions included the A-36 Allison-powered attack variant developed in 1942 and the P-82 twin Mustang that consisted of two fuselages connected by a special wing section and at the tail.

AIR WAR IN THE PACIFIC

THE JAPANESE SOUGHT TO EXPAND THEIR EMPIRE IN THE ASIA PACIFIC REGION FROM THE 1930S. BUT AS WARREN E THOMPSON EXPLAINS, IT WAS ONLY AFTER THEY ATTACKED PEARL HARBOR IN DECEMBER 1941 THAT THE MIGHT OF AMERICA FINALLY TAMED THEIR AMBITIONS.

The Bettleship *USS Arizona* lies pertlelly sunk in Pearl Herbor shortly afler the Jepenese ettack on December 7, 1941. Since the etleck wes mede before en officiel decleration of war, il only served to enger the Unlled Stales even more. (US Navy)

The pecked deck of the *USS Yorktown* (CV-10) during the 1943 campeign lo take the Gilbert Islands. The Industrial output of the Unlled Stetes rapidly gave il en overwhelming numericel and technicel edventage over the Japanese. (Warren Thompson)

From an American's point-of-view, World War Two officially started on December 7, 1941. The weeks that followed this infamous date proved to be both chaotic and brutal, especially in the Pacific. The chain of events that rapidly unfolded during that brief period involved naval forces from Japan, Britain and the United States. The United States lost most of its Pacific Fleet while the Royal Navy was dealt a serious blow when two of its finest battleships - HMS Prince of Wales and Repulse - were claimed by waves of Japanese bombers on December 10. When Wake Island fell to the Japanese on December 23, the aerial supply route to the Philippines had been cut off and the Imperial Japanese Naval forces were spread out all over the Pacific. With very little resistance on offer - it seemed that the Allies were already in dire straits by the end of December.

JAPANESE EXPANSION

Japan's plans to expand its empire began to take shape back in the early 1930s. They called for an inner zone encompassing the mainland and an outer zone to cover the conquered areas. The latter zone's sole purpose was to provide the inner zone with essential raw materials, such as rubber and oil. All of this new territory would be protected by a vast well-trained and ruthless military arm. These forces met very little resistance until they were later tested on Guadalcanal in 1942. The resident American military unit there fought a gallant fight, but it had no chance against such overwhelming odds. The only flaw in Japan's master plan was the American Navy in Hawaii. In the attack on December 7, 1941, it was counting on two factors; destroying the American Naval presence in the Pacific and that the American public would ultimately grow war weary and back away. It was Admiral Isoruku Yamamoto that accurately summed up the Japanese attack on Pearl Harbor when he stated: "We have awakened a sleeping giant and have instilled in him a terrible resolve!"

EARLY STRUGGLES

As 1942 began, the Japanese were in control in the Pacific with the British and American Navies heavily battered. There were only two places left for the Allies to begin any semblance of counter action; Hawaii and Australia. The Allied military leaders knew that the key to winning a war over such a vast expanse of ocean was building a strong navy with the emphasis on aircraft carriers. What little intelligence they could gather indicated that the Japanese had set up a very effective interlocking system of air bases that reached out from China to Malaya and on to the East Indies, and this included New Guinea and the Solomon Islands. With this system in place, the enemy did not need long-range aircraft because they could move their fighters from base to base quickly, thus enabling them to reinforce any threatened area.

The United States was caught off guard and its posture in the Pacific had been weakened to the extent that it would be difficult to prevent further encroachment by the Japanese military. A good example of this unprepared state was with the number of military aircraft in the inventory. By the mid-1938, the US had a total of 1,213 combat aircraft to hand and by July of 1941, this had only risen to 1,774. In the Pacific, early American military priorities centred on three facts: preventing the enemy from getting a foothold on the Aleutians (North America); protecting Australia and securing the transit route of supplies that had to move between the US and that valuable ally. There was also a major problem with declining public morale ▶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15
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Top: Very few heavy bombers were available to Pacific commanders in the months after Pearl Harbor. But nevertheless the handful of B-17s based in the Philippines and Australia performed heroically in an attempt to halt the spread of Japanese influence in the southwest Pacific. (www.aerothenlic.com)

Right: One of the most ambitious and daring raids of World War Two was carried out on April 18, 1942, by force of 18 B-25 Mitchells led by Lt Col James H Doolittle, against a number of targets on the Japanese mainland. (US Navy)

Above: The USS *Yorktown* (CV-5) during the Battle of the Coral Sea. Less than a month later this carrier was lost during the Battle of Midway, but the losses to the IJN were far more severe. (US Navy)

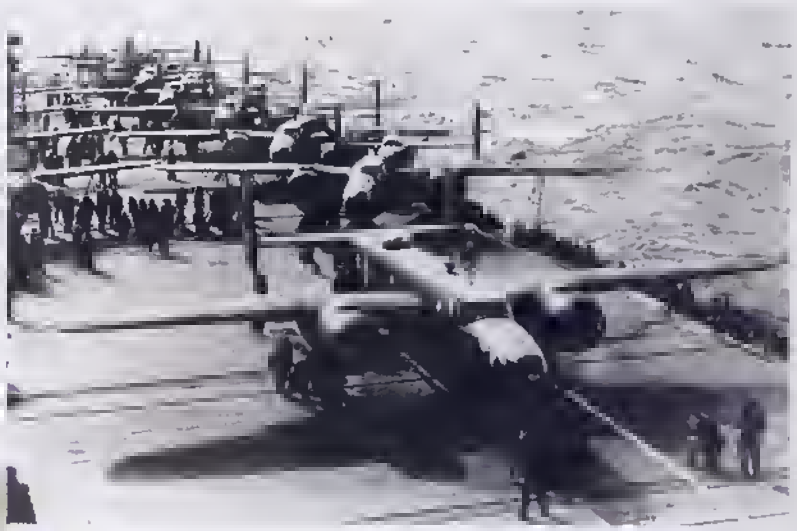
and that was taken care of on April 18, 1942, when 18 B-25 Mitchells were launched from the USS Hornet. Led by Lieutenant Colonel James H Doolittle, they successfully bombed targets within the heart of Japan; Yokohama, Tokyo, Kobe and Nagoya. This news spread all over the US and immediately garnered the will of the public to pitch in and get the job done. This same day was significant for another reason as well, General Douglas MacArthur assumed command of all military forces (Allied) in the Southwest Pacific Theatre.

Fighting Back

The American war machine was getting cranked up in 1942 and within six months it was churning out war-related products to be shipped all over the world. The Pentagon and President Roosevelt determined that the lion's share of these should go to the European Theatre with the emphasis on saving Britain from falling to the Germans. The reasoning was two-fold; the British were an important ally and having the British Isles as a starting place from which to take Europe back was crucial to the war's outcome. This left the campaign in the Pacific 'in limbo'. However, with only a handful of aircraft, ships and personnel, the Allies were able to begin to dish out some serious set-backs to Japan.

Less than one month after the Doolittle raid, a major battle took place in the Coral Sea in the southwest Pacific. The date was May 7-8, 1942, and it would be the first of six significant battles between aircraft carrier groups in the Pacific Theatre. The losses on both sides were heavy, but it derailed the Japanese attempt to invade Tulagi and Port Moresby and the damage to two of its big carriers would keep them out of the huge carrier fight that was only weeks away. The greatest loss to the Americans was one of their main aircraft carriers; the USS Lexington. If total loss of ships determined who won or lost, then the Imperial Japanese Navy (IJN) was the victor, but this was not the case. The enemy suffered a tremendous psychological blow and from this date on, it was the Japanese that were on the defensive while the Americans continually built up their offensive momentum. Days later (May 11), two carriers; USS Enterprise and Hornet delivered 21 F4F Wildcats to the Marines on New Caledonia.

On May 12, just days after the Battle of the Coral Sea, the final American humiliation, in the Pacific, occurred on Mindanao Island when the last of the US troops in the Philippines surrendered to the Japanese. For over two months, Admiral Yamamoto had been trying to convince the General Naval Staff that Midway Island, in the central Pacific, was the ideal place to attack as opposed to Samoa and the Fiji Islands. His idea was finally accepted and the show-down was beginning to shape up. The Japanese would bring in ships from all over the Empire giving them seven battleships, ten aircraft carriers 24 cruisers and 70 destroyers, plus Yamamoto's flagship the giant battleship Yamato. The Battle of Midway took place on June 4-5 with the results being disastrous for the IJN. The American fleet was led by three big carriers in this engagement; the USS Enterprise, Hornet and Yorktown. The battle resulted in the Japanese losing four carriers and the US losing the Yorktown. History would prove that the side with the edge in carrier numbers would dominate all of the future naval clashes. Midway turned out to be the final chance the IJN would have of inflicting a knockout blow to the American carrier force.



At this point, the Japanese invasion of Port Moresby was called off due to the reduction in available carrier cover (amongst other things), but there were on-going air battles over that area between Japanese Mitsubishi Zeros and American Bell P-39 Airacobras and Curtiss P-40 Warhawks. The US Fifth Air Force was building up a large number of fighters and long-range bombers that would stage from bases in Australia and New Guinea. The Boeing B-17 Flying Fortresses (19th Bomb Group) and Martin B-26 Marauders (22nd Bomb Group) made up a large portion of this force.

With American military confidence increasing, the stage was set for the first major offensive ground action that would involve the Marines. On August 7, the first amphibious assault on the Empire of the Rising Sun took place on Guadalcanal with the 1st Marine Division. This was a hard-fought conflict that would involve numerous sea battles in the 'Slot' (as the region was known) during the hours of darkness while the Marines hung on to a tenuous beachhead. It was during the night bombing attacks by Japanese bombers that the Army Air Force (AAF) realised it was in dire need of an effective night-fighter. Guadalcanal would not be declared secure until the last day of December when the Japanese stopped trying to reinforce the island, and by early February 1943 all resistance had ended. This was the first major invasion victory for the Allies in the Pacific and marked the first step on the long road to Japan.

Taking the Initiative

1943 would prove to be the pivotal year during which the Allies would gain momentum that the Japanese could not contain, and all of this would be accomplished while the war in Europe still had top priority.

Allied ground forces made great progress in defeating the Japanese during several battles on New Guinea. The biggest confrontation occurred with the Battle of the Bismarck Sea between March 2 and 4. Crucially it pitted US 5th Air Force and Royal Australian aircraft against a large Japanese convoy laden with troops that was

steaming toward Lae, Papua New Guinea. Over 160 aircraft attacked the convoy over a three-day period and when it was over, the enemy had lost eight transports, four destroyers and about 100 land-based fighters. This proved that Allied airpower had built up enough strength in the area to inflict heavy damage to anything the Japanese attempted. Official USAAF records state that in July 1942, the total number of combat aircraft in the inventory was 3,191. In contrast, one year later this had risen to 8,696. Most of these were destined for Europe, but the Pacific Theatre was

Lt Cdr 'Butch' O'Hare, the first US Navy ace of World War Two in his Grumman F4F Wildcat. (Herman Backland via author)

Left: The Consolidated PBY-5 Catalina flying-boat was one of the most significant aircraft of World War Two. Its long range made it ideal for reconnaissance missions far out to sea where it also saved the lives of many downed aircrew. (KEY collection)

getting enough to maintain a credible force.

The Americans cracked the top-secret Japanese code and one of the transmissions they intercepted was the fact that Admiral Yamamoto was going to pay a personal visit to the troops on Bougainville Island. Fortunately, the number of available Lockheed P-38 Lightnings had grown substantially and the 347th Fighter Group was in a position to meet his aircraft over the island. On April 18, 16 P-38s from the 339th Fighter Squadron timed their arrival perfectly and in a brief, but intense attack, Yamamoto's Betty bomber was shot down over the jungle along with another bomber and three Zero fighter escorts. One P-38 was lost on the mission. The Japanese never recovered completely from the loss of such a brilliant military leader.

By mid-April, the enemy foothold on the Aleutian Islands had become a thorn in the side of the 11th Air Force. For several weeks, its bombers and fighters hammered the enemy at Attu aerodrome and Kiska. Waves of P-40s and P-38s supported the bombing sorties carried out by Consolidated B-24 Liberators and North American B-25 Mitchells. On the April 18 mission, 22 P-38s and 37 P-40s took out most of the aerial resistance in the area, with many of the Lightnings being flown by seasoned Royal Canadian Air Force (RCAF) pilots. By May 10, the Japanese forces clinging to the Aleutians had been weakened from being constantly pounded by USAAF aircraft and the US Army troops landed at Attu to take care of the ground action. On the opposite side of the vast Pacific, the enemy had begun to lose key positions and its resolve at remaining in the Aleutians started to deteriorate. Historical records state that the enemy forces ended their occupation of Attu on May 31.

Based on some brilliant leadership decisions, the Allies rapidly gained momentum even though they still had a long road to Tokyo. Another major US Navy offensive began on June 11, 1943, when it embarked on aggressive submarine operations against Japanese shipping. This placed some of the subs

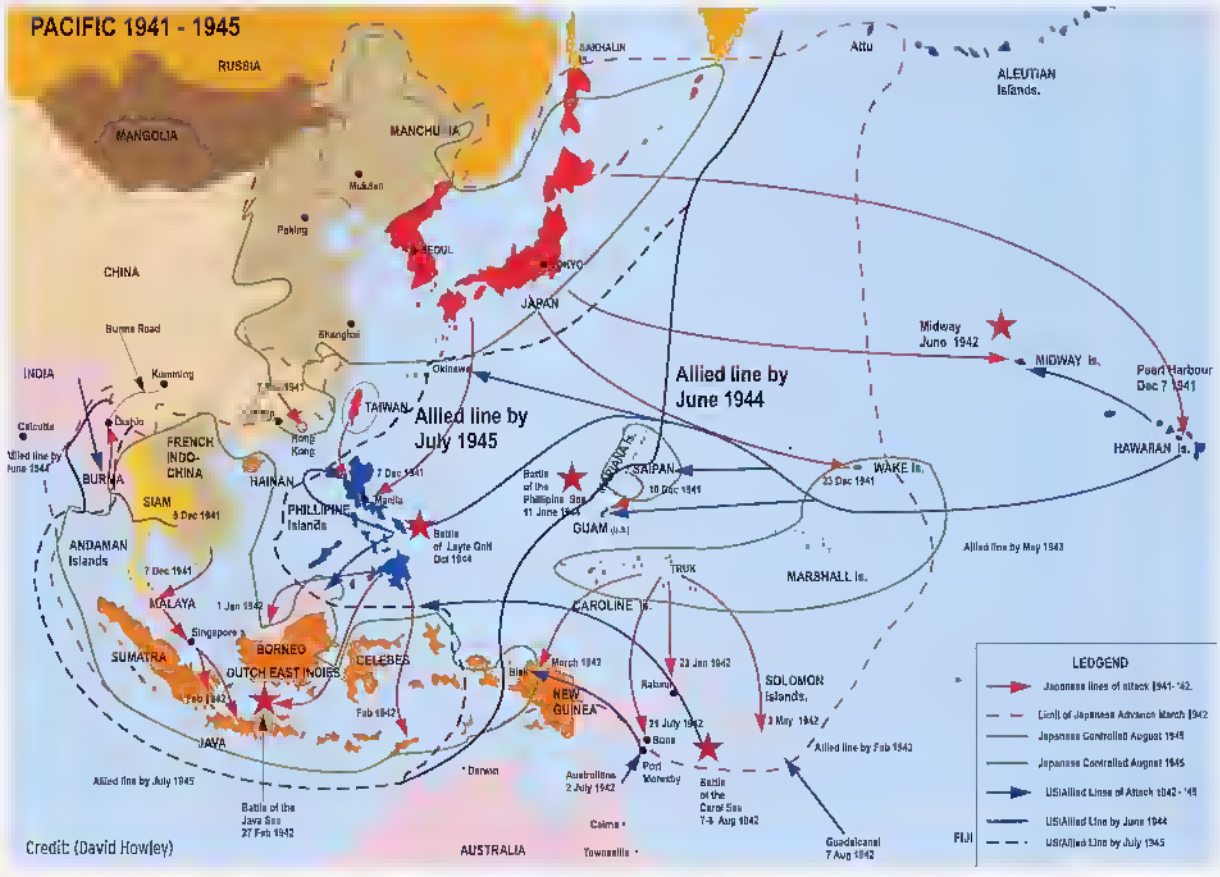
Above: It should not be forgotten that as well as the battles in the Pacific, the Allies were also fighting the Japanese in Southeast Asia. Here USAAF B-25 Mitchells fly over the Burmese jungle. (US National Archives)

Left: The primary Japanese fighter was the Mitsubishi A6M Zero. Although it was a highly capable aircraft, it failed to keep pace with improving American designs and in the latter stages of the war was hopelessly outclassed. (Planes of Fame Museum)

in the mouth of Tokyo Bay, a heavily defended area and highly dangerous for submarines. Meanwhile back in the USA the aircraft factories of Consolidated and Boeing were now producing bombers much faster than the loss rate and many of the new B-24s were sent to the Pacific Theatre. By the first week of June, the consequences of the Japanese failing at Midway, had started to come back and take effect. A large number of Liberators operating from Midway did substantial damage to Japanese fortifications on Wake Island. Within four months, Midway had become an armed fortress jammed with long-range bombers.

Continued success

With the loss of Guadalcanal, the other islands in the Solomon chain were prime targets for the Allies and the pressure was now really on. As the US Navy began assembling a fleet at Guadalcanal to invade the central part of the Solomons (New Georgia in Operation 'Toenail'), the Japanese threw everything they could ▶



Below right: **The undoubted hero of the Battle of Midway was the Douglas SBD Dauntless dive bomber. It accounted for four IJN heavy carriers during the battle and continued to be a highly accurate bombing platform for the rest of the war.** (Ed Szrejter via author)

Below: **The Curtiss P-40 was used extensively by the USAAF and other Allied forces in the southwest Pacific. Illustrated is a P-40 of the 26th FS/51st FG in the China, Burma, India (CBI) theatre of operations.** (Dick Starinchak via author)

Right: **A Grumman TBF Avenger gets the signal to take off from the USS *Lexington* in November 1943 for a strike against Mill Island.** (US National Archives)

at it. On June 16, close to 100 IJN fighters and bombers were en route to attack the ships, when they were intercepted by approximately 100 Allied fighters (USAAF, Navy and Marines) along with pilots from New Zealand flying Curtis Kittyhawks. The fight lasted 35 minutes and most of the enemy aircraft were shot down, with only six friendly aircraft lost. This sent a message to the Japanese command in the SW Pacific that it would take far more than this to stop the momentum of the Allies. Less than one week later, Marines and US Army troops successfully landed around Munda Point on New Georgia and met very little opposition.

By late June, the Navy and Marines were beginning to achieve very high victory claims against enemy fighters using their new Hellcats and Corsairs. At about this same time, another future fighter legend was unleashed in the Pacific - the Republic P-47 Thunderbolts of the 348th Fighter Group, fresh from training in the States. This unit went on to be acclaimed as the most successful in the Pacific Theatre. Fortunately for its aircrews, when they entered combat, the skies were still full of Japanese aircraft, so the hunting was good.

COMMANDING THE NIGHT

There was great demand for effective night fighters in the SW Pacific because it was almost impossible for Japanese fighters to get through the day fighter screens to attack any valuable Allied assets. Thus, they had to try to accomplish this during the hours of darkness. The stop-gap Douglas P-70s (A-20 Havocs that had radar and 20mm gun pods) were not able to get up to the enemy bomber's altitude, so the 6th Night Fighter Squadron obtained a few P-38 Lightnings that would work with the P-70s long enough to get a visual. On July 12, they scored their first kill in the Lightning. The highly touted Northrop P-61 Black Widow night fighter was still undergoing tests before its production run and didn't enter service until later in the war.

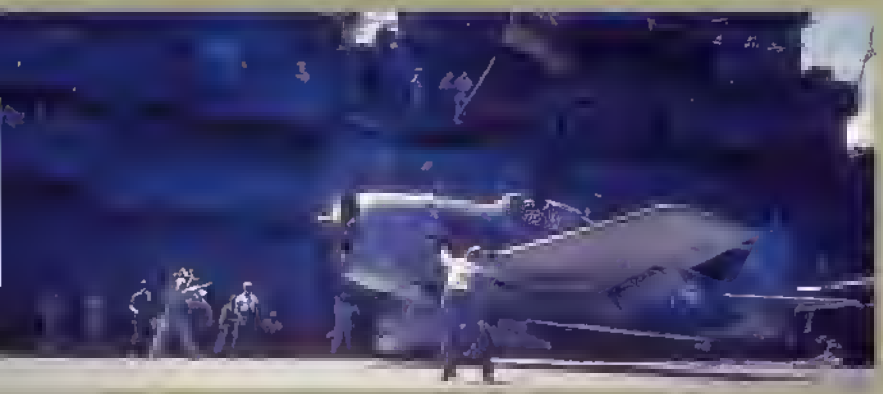
The Marines were almost ready with their first effort into the nocturnal mission with the Lockheed PV-1 Ventura. In early September, VMF(N)-531 would be tasked with testing night fighter tactics gleaned from the RAF in its battle against the Luftwaffe during the Blitz. Several months after the Venturas got into action, the Marines transitioned onto the new radar-equipped Hellcats and Corsairs, and became very effective in the night intercept role.

Left: **Japanese use of the kamikaze tactic during the final months of the war caused considerable damage to many Allied ships. However, in the end it made no difference to the outcome of the war.** (KEY collection)

incident that later received worldwide publicity as the skipper of PT-109 was none other than John F Kennedy, future President of the United States. Most of the IJN ship movements were carried out at night because of the intense pressure put on them by Allied aircraft during the day. The PT boats were tasked with trying to hinder the enemy at night.

The US Army achieved a sizable build-up in the southwest Pacific in the early summer of 1943, and by mid-August was ready to begin its offensive on Lae. To make sure there would be no undue interference with the landings, the 5th Air Force began neutralizing the huge aerodrome complex at Wewak, which had satellite strips at Boram, But and Dagua. Action began at 03.00 when 36 B-24s and 12 B-17s attacked all four airfields with incendiary and para-frag bombs. At first light, a large number of B-25s came in at tree-top level to 'clean up' any damaged aircraft left on the ground, followed by an impressive force of 85 P-38s. The closely-timed strikes caught the enemy aircraft by surprise and almost wiped out their presence in the area. With very little opposition, the P-38s were able to inflict heavy damage to the heavy barge traffic encountered

Below left: **The speed and manoeuvrability of Grumman's F6F Hellcat, developed from the earlier F4F Wildcat, helped determine the outcome of many air battles in the Pacific. This example from VF-5 is seen aboard the USS *Yorktown* (CV-10) in August 1943.** (Warren Thompson)



Unacceptable losses

In mid-July, the IJN made a last attempt to block Allied operations in the Central Solomons. A large formation of 27 Mitsubishi G4M Bettles and 40 Mitsubishi A6M Zeros were intercepted by an aggressive force of aircraft from nearby bases. Three Allied fighters went down in the mêlée, for 45 Japanese aircraft shot down. These constant losses to overwhelming numbers of Navy, Marine and Army Air Force fighters took their toll on the enemy, whose only remaining strategy was to pull back its dwindling reserves of aircraft to light further to the north. The Empire had begun to shrink on all sides.

Another milestone was achieved on July 31, 1943, when the 'Wake Island Avengers' from VMF-223 returned to the Pacific in new F4U Corsairs. Eager for combat, they arrived on Midway Island following re-organization and re-training in the States. At the same time, VMF-222 launched its F4Us from Midway en route to their new base on Espiritu Santo - from now on, the enemy would look up and see swarms of Marine Corsairs and Navy Hellcats. Their growing numbers seemed to engulf any Japanese effort to make a strong showing.

On the night of August 1-2, there was a clash between large IJN ships and 15 American PT boats south of Kolombangara Island, in the Solomons. One of the latter was crushed by a Japanese cruiser, with two of its crew killed, an - this being the primary method by which the Japanese reinforced smaller islands lacking port or unloading facilities for larger ships.

US Navy carriers continued to position themselves close enough to Japanese shipping to successfully send out aircraft on continuous strikes. On August 30, 1st Lt Kenneth A Walsh, a Marine Corsair pilot from VMF-124, downed four enemy aircraft on same mission, bringing his personal total to 20 kills, an exploit which earned him the Medal of Honor. Two weeks later, on September 16, Major Gregory Boyington, commanding officer of VMF-214, brought down five Japanese fighters - this, combined with the six kills he had with the AVG, made him a double 'ace', a famous landmark in the history of the 'Black Sheep Squadron'.

By the third week of September, IJA forces had all but pulled out of the central Solomon Islands, the previous loss at Guadalcanal continuing to haunt them. From Henderson Field, ▶

Above: **The Douglas P-70, a night fighter version of the A-20 Havoc, was only a stop-gap measure until a more effective night fighter could be deployed.** (Fred Secord via author)

Left: **A Grumman F6F Wildcat about to touch down on the USS *Lexington* (CV-16) during the battle of the Philippines Sea on June 19, 1944. The one-sided air battle quickly became known as the 'Great Marianas Turkey Shoot'.** (US Navy)

Extraordinary nose art worn by B-24 Liberator 'It Ain't So Funny' depicting many famous cartoon characters of the period. (Edward Egan via author)

Far right: The P-47 Thunderbolt proved to be just as effective as a fighter bomber in the Pacific as it did in Europe. (US National Archives)

A night fighter variant of the Vought F4U Corsair operated by VMF(N)-532 awaits its next mission on Saipan in July 1944. (Willis Coates via author)

Guadalcanal, AAC fighters and bombers ranged out and destroyed countless targets in the northern Solomons, the enemy's only major resistance coming from aircraft from their big base on Truk. This began to put a strain on Japanese land-based pilots as they now had to fly long distances over water, many of their aerodromes throughout the Solomons having been rendered unusable by American fighter sweeps.

One of the bloodiest battles in the Pacific began on November 20 when the Marines landed on Tarawa in the Gilbert Islands, the most south-easterly point held by the Japanese and one of their most-heavily fortified bases in the region. The Gilbert Islands were seen as a major objective, and the action here was also the Marines' first major amphibious operation of the war. A thousand Marines were killed during the three days it took to secure Tarawa, but of the 4,800 defenders, only 17 survived. Meanwhile the Army was mopping up in New Guinea but the Navy and AAF were stretched out trying to support all operations. Fortunately, the number of aircraft being sent into the Pacific Theatre was sufficient to start pushing the enemy back toward Japan; USAF records for the period July 1, 1943, to July 1, 1944, show an increase of 13,420 available combat aircraft. The Axis powers were being overwhelmed in all theatres by airpower and the number of warships.

Heading for Victory

The year 1944 began with encouraging news for the Allies. On January 31, a large invasion fleet converged on Kwajalein and Majura Atoll in the Marshall Islands. By February 7, the islands were secure and one was quickly converted into a major airbase, putting many more Japanese strongholds within reach. Ten days later, the enemy's super-base at Truk was rendered useless by one of the biggest Navy Air efforts of the war. This strike involved everything Task Force 58 had - TBFs, SB2Cs, Douglas SBDs and 72 Grumman F6F Hellcats – destroying over 150 enemy aircraft on the ground and attacking the 50 enemy transports and four warships in the lagoon. However, this action served to wake up a hornets' nest in that scores of Japanese fighters were able to get into the air, but to little avail. When the battle was over, another 121 Japanese fighters had gone down in flames.

There were two major enemy bases in the Pacific which would have to be bypassed by the ground forces and neutralized by airpower. Truk had already been on the receiving end of a massive attack; the final objective would be Rabaul, which was attacked on February 20 by a virtual armada of aircraft. The day before the strike, several Japanese ships had managed to sneak in and had attempted to evacuate a large number of enlisted aircraft specialists, who were crucial to keeping the dwindling number of fighters and bombers in the air. Caught off the coast of New Ireland, two of them were sunk by aggressive, low-flying B-25 Mitchells; the rest were damaged and the enemy suffered heavy casualties. The USAAF sent 15 of its B-24 Liberators over Rabaul's Lakunai aerodrome,

Abandoned Japanese aircraft await their fates on Formosa in the summer of 1945. (Bill Ward via author)

Right: B-25 Mitchells of the 47th BS/41st BG prepare to leave Okinawa in July 1945 for an anti shipping mission armed with torpedoes. (US National Archives)

cratering the runways and destroying enemy aircraft parked along the tree-line. In support of this effort, Navy and Marine TBFs and SBDs went in low to take out anti-aircraft gun emplacements. Within the space of three days, Japan had lost two of its biggest support bases with no Allied ground troops involved.

Enter the Superfortress

In the late spring of 1944, the new Boeing Superfortresses were finally in a position to begin combat operations, initially flying out of Karachi, India. On June 5, the 58th Very Heavy Bomb Group launched its first attack against rail yards in Bangkok, Thailand. This was carried out in bad weather by 77 B-29s, a large percentage of which had to use radar to make their drops. This was the first of many occasions on which Japanese forces would witness the devastating effects of this new bomber.

Less than two weeks later, staging from forward bases at Chengtu, China, another large formation of B-29s from the 58th Bomb Group pulled off the first aerial attack against Japan since the Doolittle Raid of 1942. The target was a steel plant at Yawata, Japan, which absorbed 221 tons of bombs from the attack. One B-29 went down from anti-aircraft fire and five more were lost due to operational accidents. However, enemy intelligence was able to get a general idea of where the bombers had launched from and a detachment of P-61 Black Widows had to be brought in to protect the Chinese base from night attacks by Japanese bombers.

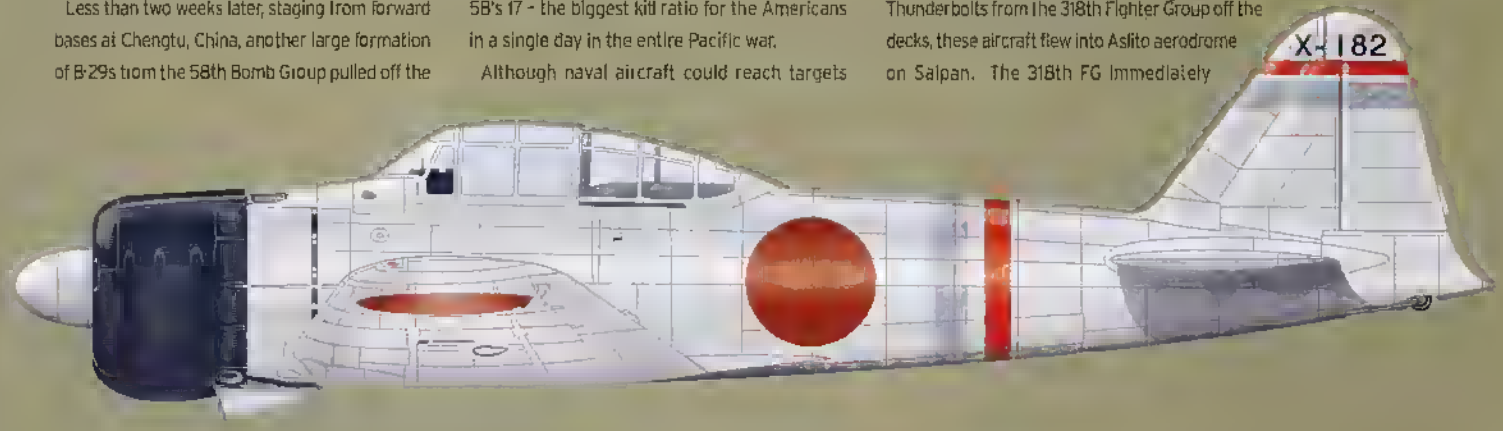
Closing in

As the Japanese sphere of influence continued to implode toward the Japanese mainland, the intensity with which they fought increased. The next 'hot spot' in the Pacific were the Mariana Islands. This was the scene of the Battle of the Philippine Sea, which in turn led to one of the most publicized air battles in history, the 'Marianas Turkey Shoot'. The date was June 19, 1944, and Task Force 58 was about to face as many as 430 IJN carrier aircraft. At 10.30 that morning, radar from the USS Lexington picked up waves of enemy aircraft converging on the fleet. A dozen Hellcats were immediately launched to intercept them. The number of aircraft swept into the fight rose as the morning wore on, and the dogfights spread out over a wide area, lasting well into the afternoon. By the time the battle ended, the Japanese had lost over 350 aircraft to Task Force 58's 17 - the biggest kill ratio for the Americans in a single day in the entire Pacific war.

Although naval aircraft could reach targets beyond the range of the land-based fighters, the engineering battalions were carving airfields out of newly-captured islands, keeping USAAF P-38s, with their long-range tanks, at the forefront of operations. However, by this time, the P-47 Thunderbolt had become available in sufficient numbers to begin using its ground attack capabilities against some of the Japanese-held islands. Three days after the 'Turkey Shoot', two escort carriers moved in towards the Mariana Islands, their decks loaded with P-47s. The Manila Bay and Natoma Bay launched a total of 73 Thunderbolts from the 318th Fighter Group off the decks, these aircraft flew into Aslito aerodrome on Saipan. The 318th FG immediately loaded up with rockets and began supporting Marine ground troops on Saipan.

The Battle of Leyte Gulf also ushered in a new and deadly form of warfare - the Kamikaze (Devine Wind). The decisive US naval victory here sparked off acts of desperation within the Japanese military, forcing the use of the suicide tactic. On October 25, the first suicide

B-24 Liberators await their next mission on Okinawa on July 27, 1945. (US National Archives)



A6M2 X-182 of the 23rd Hikotai, Ambon Island, circa 1942. (David Howley)

A Kawasaki Ki-61 Tony partially camouflaged is inspected by American personnel on an overrun Japanese airfield. (US National Archives)

This Japanese Mitsubishi G4M Betty bomber was used to transport the Emperor's envoys to the signing of the surrender documents on September 2, 1945. (Wilbur Kuhn via author)

A B-29 of the 501st BG takes a break on Guam in 1945. The destructive power of the B-29 with conventional high explosive and incendiary bombs was phenomenal – but it was soon to become even more deadly. (Ed Hering via author)

Right: B-29 *Enola Gay* delivered the first atomic bomb on Japan on August 6, 1945. (US National Archives)

aircraft made a strike against Allied ships, a tactic which reached its peak in the assault on Okinawa a few months later. By the time the war in the Pacific ended, the Japanese had sent over 2,200 kamikaze pilots out to certain death as the strength of the Allied forces rose. The US Navy's Admiral Halsey made a statement after the war stating that the only weapon he had actually feared was kamikaze warfare.

As 1944 drew to a close, the only major obstacles remaining were Iwo Jima, Okinawa and Japan itself. Iwo Jima was critical – it would prove a safe haven for B-29s unable to make it back to Saipan due to battle damage, and it would allow the long-range P-51 Mustangs to escort the B-29s all the way to targets in Japan. Iwo Jima was invaded by the Marines on February 19, 1945, and when B-29s flew their first fighter-escorted missions over Japan on April 7, the P-51 escorts were based there. Five days later, President Franklin Roosevelt died which seemed to temporarily lessen public interest in the recent victories in the Pacific.

Below: As a memorial to those killed at Hiroshima the iconic domed building that was one of the few structures left standing after the attack has been left entirely as it was.

THE ULTIMATE WEAPON

May 1945 brought two major historical events – the end of the war in Europe, and approval of the final plans for the invasion of Japan (Operation Olympic); the date being set for November 1. In June, Okinawa and the Philippines fell to Allied forces. The level of casualties and the fanatical Japanese defence gave warning of the potentially costly ground campaign in Japan. Japanese Premier Suzuki also stated that the Japanese people would fight to the end and never accept unconditional surrender.

As tension mounted about what had to be done to end the war, a top-secret USAAF unit arrived on the fortress of Tinian to begin practice missions in anticipation of orders to drop the atomic bomb on Japan. The USS Indianapolis safely delivered the components for the first bomb to Tinian on July 26.

By the end of July, all eyes were focused on Japan as large numbers of military personnel who had fought in Europe were slowly funnelled to the Far East ahead of the anticipated invasion. Marine, Navy and AAF aircraft had significantly contributed to the collapse of the Empire, but the worst still seemed to be ahead of them. On August 6, the picture began to change when the 509th Composite Group, operating from Tinian, dropped the first atomic bomb on Hiroshima. There was no response from the Japanese Government, so a second was dropped on Nagasaki three days later. As a direct result of the latter mission, Emperor Hirohito agreed to an unconditional surrender, though his decision was not announced until August 14 (five days after the second bomb was dropped). On September 2, 1945, a formal surrender ceremony was held on the deck of the battleship USS Missouri in Tokyo Bay.

US Government records show that by July 1945 the total number of military-related aircraft in the inventory had reached a staggering 40,912. Of these, 29,125 were combat-related, over 8,000 flew in the training role and the remainder were support aircraft. These statistics, along with the large number of aircraft carriers positioned within striking range of the Japanese mainland, reflected Admiral Yamamoto's comments after the Pearl Harbor attack in December 1941: "All we have done is awaken a sleeping giant". The war in the Pacific was won collectively by all branches of service across the Allied forces. However, it was airpower that reached deep into the heart of Japan and destroyed its ability to wage war.

Even before late 1941, when the Boeing B-17 Flying Fortress was first used in anger, in January 1940 the US War Department had issued a specification for its replacement. The new aircraft was to be a four-engined long-range bomber, though after America entered the war in December 1941, the specification was later modified to reflect combat experience, leading to added requirements for defensive armament and payload.

The result was the B-29 Superfortress and the prototype XB-29 made its first flight on September 21, 1942. The aircraft featured many complex systems and innovations, including pressurisation of the crew compartments for high altitude operations. Power was provided by four Wright R-3350 18-cylinder twin row radial engines, each producing 2,200hp. Armament comprised four remotely-controlled, electrically-operated gun turrets, each housing two .50 calibre machine guns, plus a tail turret armed with two machine guns and a 20mm cannon. The aircraft could carry a bomb load of up to 20,000lb (9,080kg).

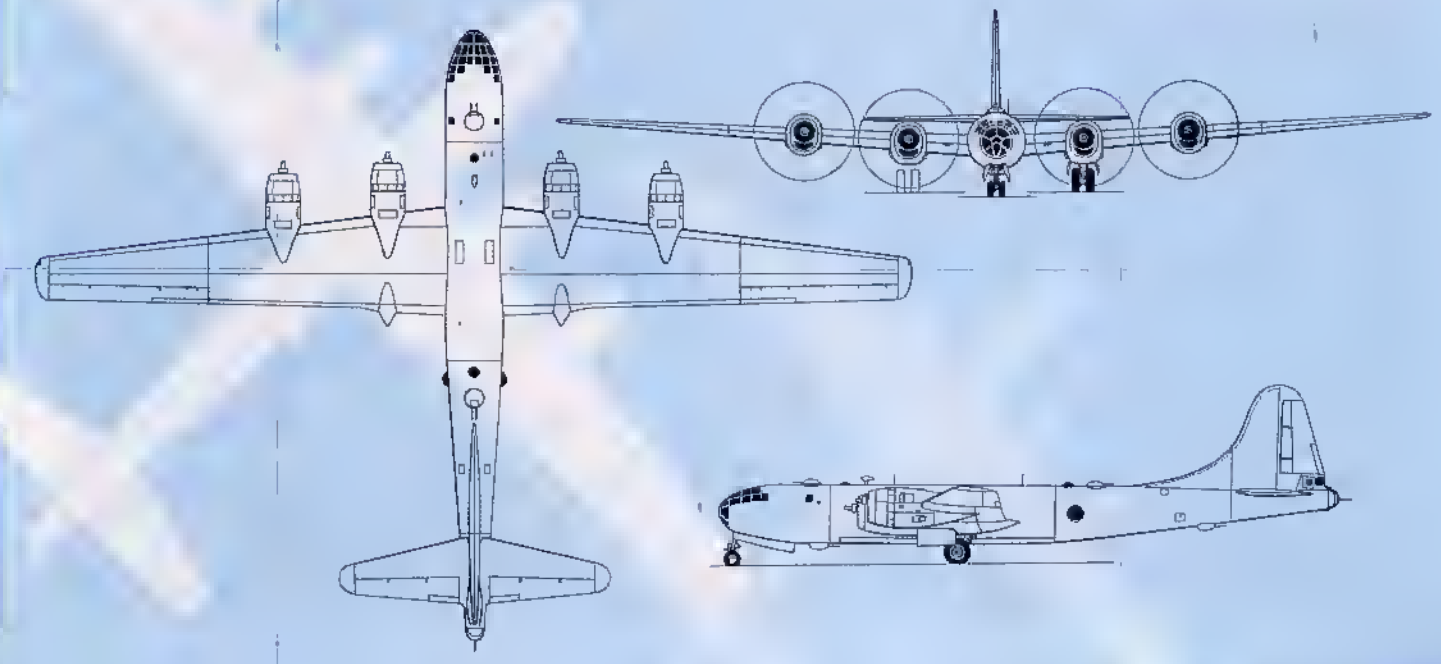
The new bomber had to be fast in order to counter the increasing speed of fighters, and with this in mind, a high aspect ratio cantilever wing was sited at the mid-point of the fuselage sides. The use of large Fowler flaps gave it a slow enough landing speed of around 100mph (160km/h).

The world's only airworthy B-29 is B-29A 44-62070 'Fifi', flown by the Commemorative Air Force and based at Midland, Texas. (KEY · Steve Fletcher)

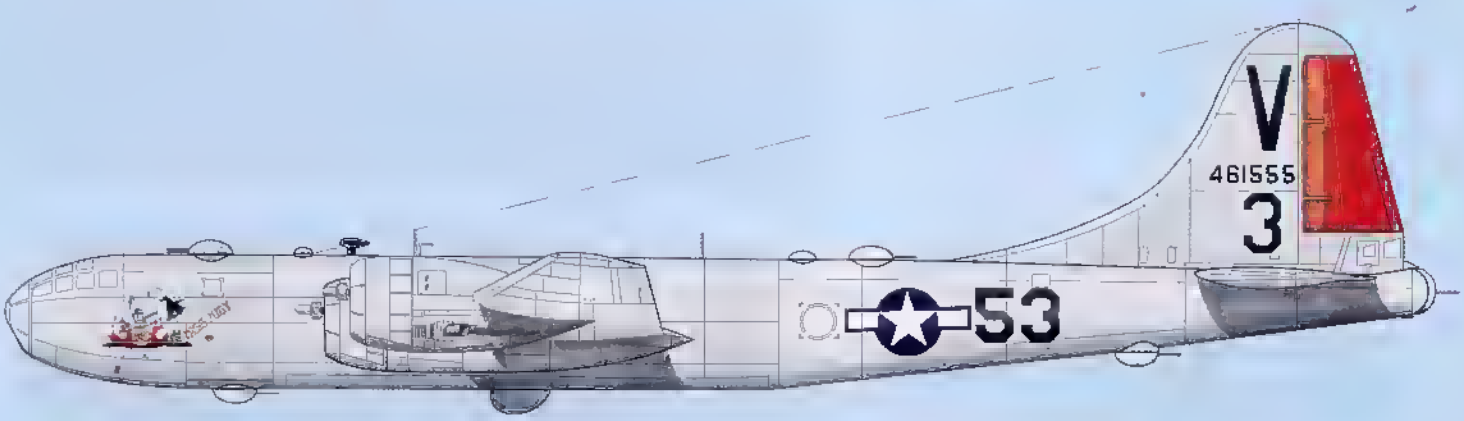
SPECIFICATION

B-29

Wingspan	141ft 3in (43.1m)
Length	99ft (30.2m)
Height	27ft 9in (8.46m)
Gross Weight	124,000lb (56,245kg)
Max Speed	358mph (576km/h)
Service Ceiling	35,000ft (10,680m)
Range	3,250miles (5,230km)
Armament	10 x 0.50 calibre machine-guns, 1 x 20mm cannon
Powerplant	4 x Wright R-3350



As this wartime image shows, the B-29 had a two-part bomb bay and was able to carry a formidable war load over considerable distances. (KEY collection)



B-29A-35-BN, 44-61555, 'Miss Judy' of the 462nd BG, based in India, circa autumn 1944. (David Howley)

Worthy of mention are the amazing manufacturing processes developed by Boeing and other companies to build the aircraft. Produced at five plants by three aircraft companies, the B-29's massive chain of suppliers and sub-assembly manufacturers must rate it as one of the greatest manufacturing efforts in American history. Eventually, the combined production by Boeing, Bell and Martin reached almost 4,000, an impressive total considering the aircraft's cost and complexity.

During World War Two, the B-29 was flown exclusively in the Pacific and Far East theatres. Its first use was from bases in China, but as the Japanese were gradually pushed back west across the Pacific, so new bases became available on various Pacific islands from which B-29s could strike at Japan itself. It proved a highly effective bomber, able to deliver a heavy load very accurately by day and night (thanks to radar-aided bombing). A pair of B-29s delivered the final blows of World War Two when they dropped two atom bombs on Hiroshima and Nagasaki in August 1945.

Right: The B-29 cockpit had a very 'glasshouse' feel to it, due to the extensive glazing at the nose. (KEY - Duncan Cubitt)

Oozing power, the Commemorative Air Force's B-29A 'Fifi' taxis out for another display. Noticeable here are the thickness of the high aspect ratio wing and the four massive Wright R-3350s. (KEY - Duncan Cubitt)

ODDITIES

As well as all the well-known aircraft types which took part in World War Two, plenty of designs - for one reason or another - never made it into front line service. Many nations involved in the conflict commissioned dozens of prototypes from numerous manufacturers to meet a wide variety of specifications, and while some were successful, others were quickly sidelined and forgotten.

Leading the way from an aerodynamics point of view was Germany, whose aviation industry designed some quite extraordinary aircraft in the final years of the war. A great deal of this technology was subsequently employed by Allied nations after fighting ended. Once the USA entered the war in December 1941 its vast aerospace industry began mass-producing many famous aircraft, though at the same time many other designs were tested and then dropped. Here is just a glimpse of some of the more unusual aircraft of World War Two.

Another attempt at building a fast interceptor aircraft was made by Curtiss Wright with the XP-55. A company funded concept aircraft (the CW-24) was built first and then an order from the USAAF awarded a contract for three prototypes in July 1942. Low speed handling was poor and the concept was soon abandoned.

Easily one of the strangest aircraft of World War Two, the Chance Vought V-173 demonstrator arguably coined the phrase 'flying saucer'. Its unusual shape was designed to give it a speed range from 20mph (32km/h) to 460mph (740km/h). Only the demonstrator flew: a single XF5U-1 prototype was subsequently built but never took to the air.

Among the many German designs that showed great promise but never reached front line units was the Dornier Do 335. This aircraft featured two engines, one fore and one aft of the cockpit, driving puller and pusher propellers respectively. The first example flew in October 1943, but only around 40 were built and these only made it as far as a test unit in early 1945. (KEY collection)

The Bachem Ba 349 Natter was one of a number of seemingly desperate attempts by the Germans to find ways of combating the increasingly large American daylight bombing raids. It was designed as a rocket-propelled interceptor, armed with 24 unguided rockets in the nose, and was launched vertically with the aid of booster rockets. After combat, the pilot had to bail out as there was no landing gear. This example is part of the Smithsonian collection. (KEY collection)

The German Horten brothers produced some fairly radical tail-less aircraft during World War Two, including this Ho IV glider. It paved the way for powered versions, one of which – the Ho IX – employed two early turbojets. (KEY - Duncan Cubitt)

The Northrop XP-56 was planned as an advanced fighter and was the first aircraft to feature an all-magnesium, all-welded airframe. It was powered by a Pratt & Whitney R-2800 Double Wasp radial engine, mounted in the rear fuselage and driving contra-rotating propellers. Only two prototypes were built before the project was cancelled. (Northrop)

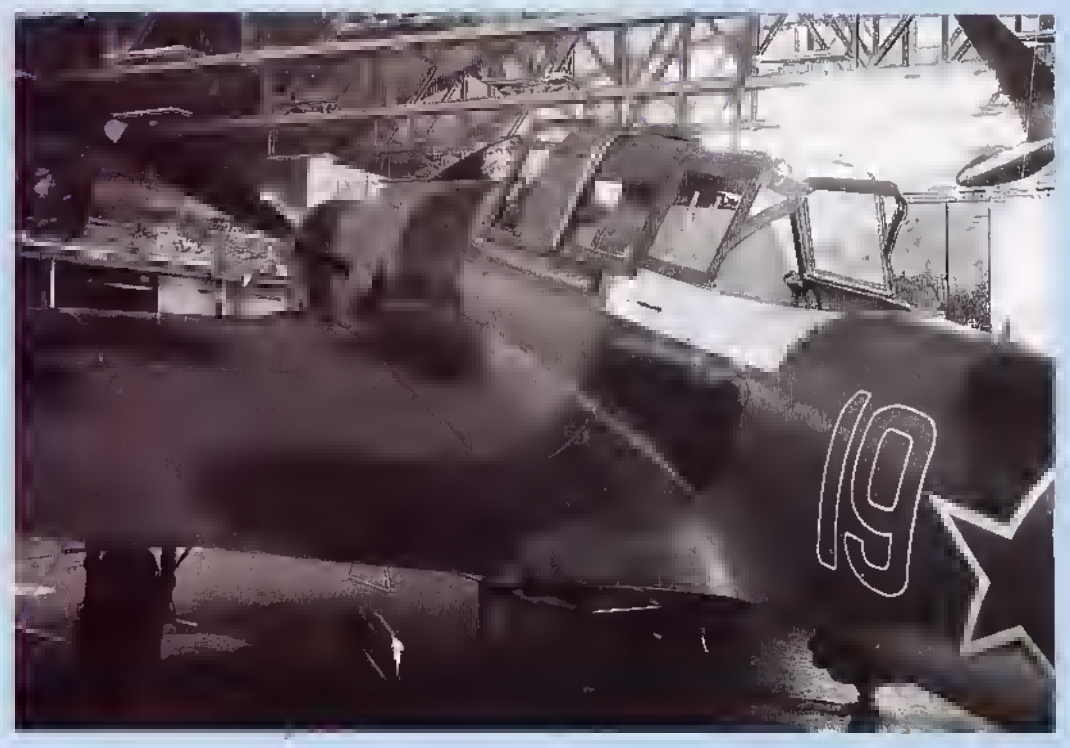
The sole surviving example of 18 Budd Conestoga transport aircraft is pictured at the Pima Air and Space Museum, Tucson, Arizona, minus wings and tail. The Conestoga was revolutionary in that it was built mostly of stainless steel, in an effort to make use of materials other than alloys. It also featured an upswept tail and rear loading ramp, now common features on military airlifters. The type never saw military service but 14 were sold to the National Skyway Freight Corporation for commercial use. (KEY - Dave Allport)

The Airspeed AS.39 Fleet Shadower, of which only one was built, was a most unusual four-engined design aimed at meeting an Admiralty specification for an aircraft to track enemy fleet movements at night. The requirement stipulated a very slow stalling speed which would allow it to maintain station, and while its maximum speed was 126mph (202km/h) its minimum speed was as low as 33mph (53km/h) at sea level.
(KEY - Gordon Swanborough collection)

Designed by Sergei V Ilyushin, more Il-2s were built than any other aircraft in history - around 36,163 examples. The Stormovik was intended to be a two-seat ground attack aircraft with an emphasis on knocking out enemy tanks. The prototype was designated the TsKB-55 and featured a protective armoured shell which formed an integral part of the airframe. This shell contained the crew compartment, the engine, fuel tanks and the oil system, thus affording them added protection against ground fire.

Early in the development phase it was decided that the aircraft should be a single-seat attack bomber and so Ilyushin converted the first prototype, which was redesignated as the TsKB-57 (later given the military designation BSh-2 which was replaced by Il-2 in January 1941). This aircraft was faster at low-level and could be armed with a variety of machine-guns, cannon, bombs and rockets. Full-scale production was finally authorized in December 1940 and the type was just entering service with the Soviet Air Force when Germany invaded Russia in June 1941.

Its heavy armour protection earned the Stormovik the nickname the 'winged tank' and it was to prove to be one of the most effective Soviet aircraft of the war. Numerous different variants were

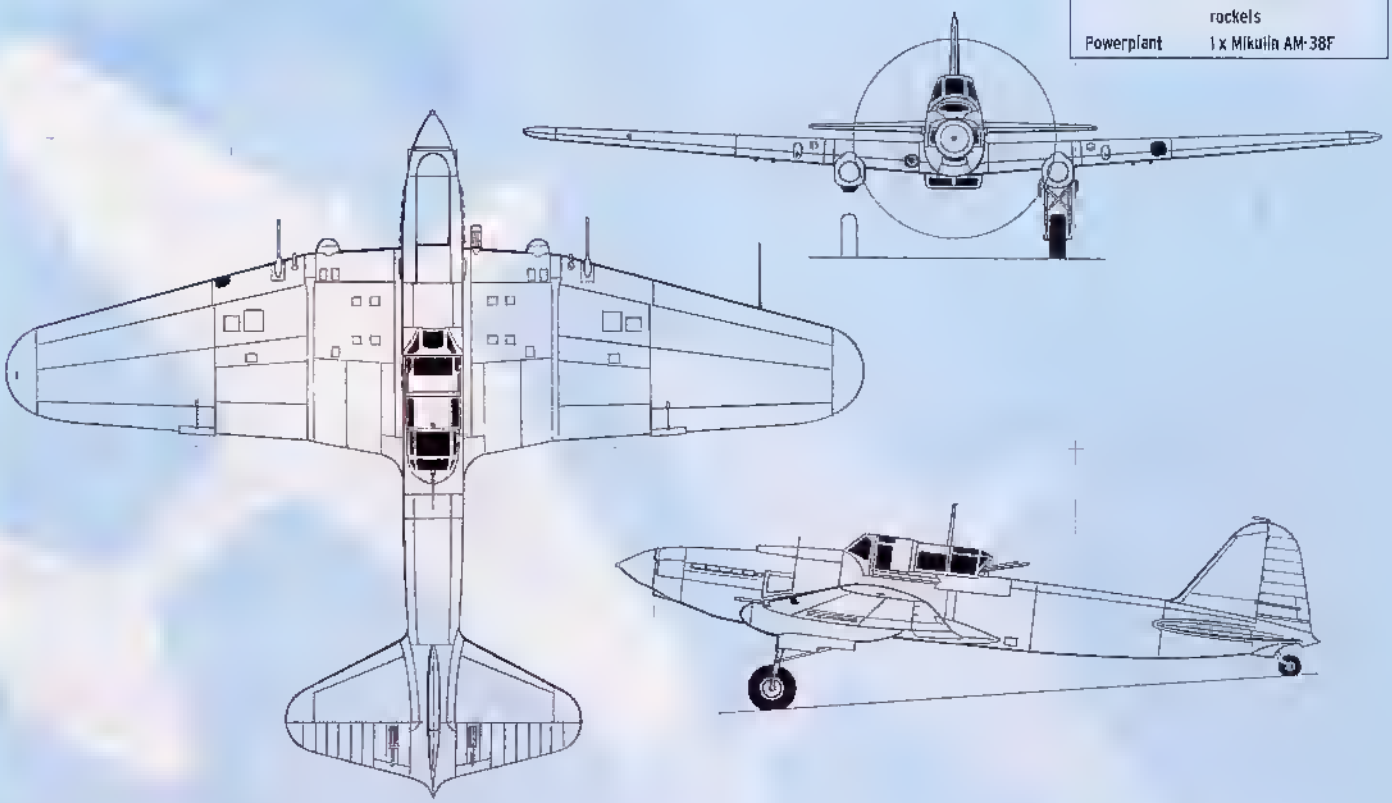


Despite its rather austere appearance, the Il-2 was an extremely practical ground attack aircraft. The whole of the centre section of the aircraft was an armoured shell to protect the most vulnerable parts of the aircraft. (David Stephens collection)

SPECIFICATION

IL-2M3

Wingspan	47ft 10¾in (14.60m)
Length	38ft 2½in (11.65m)
Height	13ft 8in (4.17m)
Gross Weight	14,021lb (6,360kg)
Max Speed	255mph (410km/h)
Service Ceiling	14,845ft (4,525m)
Range	475 miles (765km)
Armament	2 x 23mm VYa cannon & 2 x .3in machine-guns up to six 220lb (100kg) bombs & 8x RS-82 rockets
Powerplant	1 x Mikulin AM-38F



produced and in February 1942 it was decreed that the gunner and the rear cockpit should be reinstated. This variant was called the IL-2M in the West, although Soviet records do not differentiate between single and two-seat models this way. Larger 23mm cannon where soon added and then a redesigned wing was fitted to the IL-2M3 which considerably improved performance and handling – this was the most numerous and successful version of the type.

Worth mentioning here is the extraordinary efforts made by Russian industry and its workforce to produce this aircraft in such massive numbers. Il-2s were initially built at the GAZ-18 (GAZ - State Aircraft Factory) aircraft plant at Voronezh near Moscow. As the

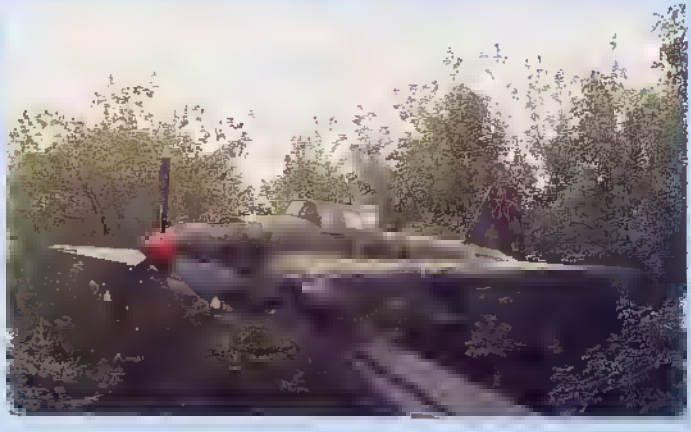
An Il-2M in typical Soviet camouflage.
(Pete West)

Germans advanced during 1941 this plant and many others came within range of Luftwaffe bombers, and so in October 1941 orders were given to move production to new facilities east of the Ural Mountains over a 1,000 miles (1,609km) away. By January 1942 some 1,523 factories and ten million workers and their families had been moved. Production recommenced after a 35-day break and in order to produce aircraft quickly fine tolerances and careful craftsmanship were ignored. The new plant at Kuibyshev was producing five aircraft a day in early January 1942, by the spring this total had risen to 40 aircraft a day.

Despite its armour protection, the Il-2 was vulnerable to the much faster Luftwaffe fighters and losses on the Eastern Front were extremely high. However, the type proved highly effective against German troops and armour, and was a decisive factor in stemming the German advance into the Soviet Union and ultimately pushing the invaders back.

Top: **The Yugoslavian Air Force Museum in Belgrade has this Il-2M on display – the Yugoslavian Air Force flew 213 of the type in the latter stages of the war.**
(KEY - Duncan Cubitt)

Above: **The Il-10 was developed from the Il-2M3 in early 1944 and included many refinements over the earlier design; in effect it was a completely new aircraft. Production totalled over 6,100 examples from Soviet and Czech factories and continued well after the war was over.**
(David Stephens collection)



Right: **The Il-2 is best known for its ruggedness and strong construction, as well as the bravery of its crews.** (KEY collection)

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